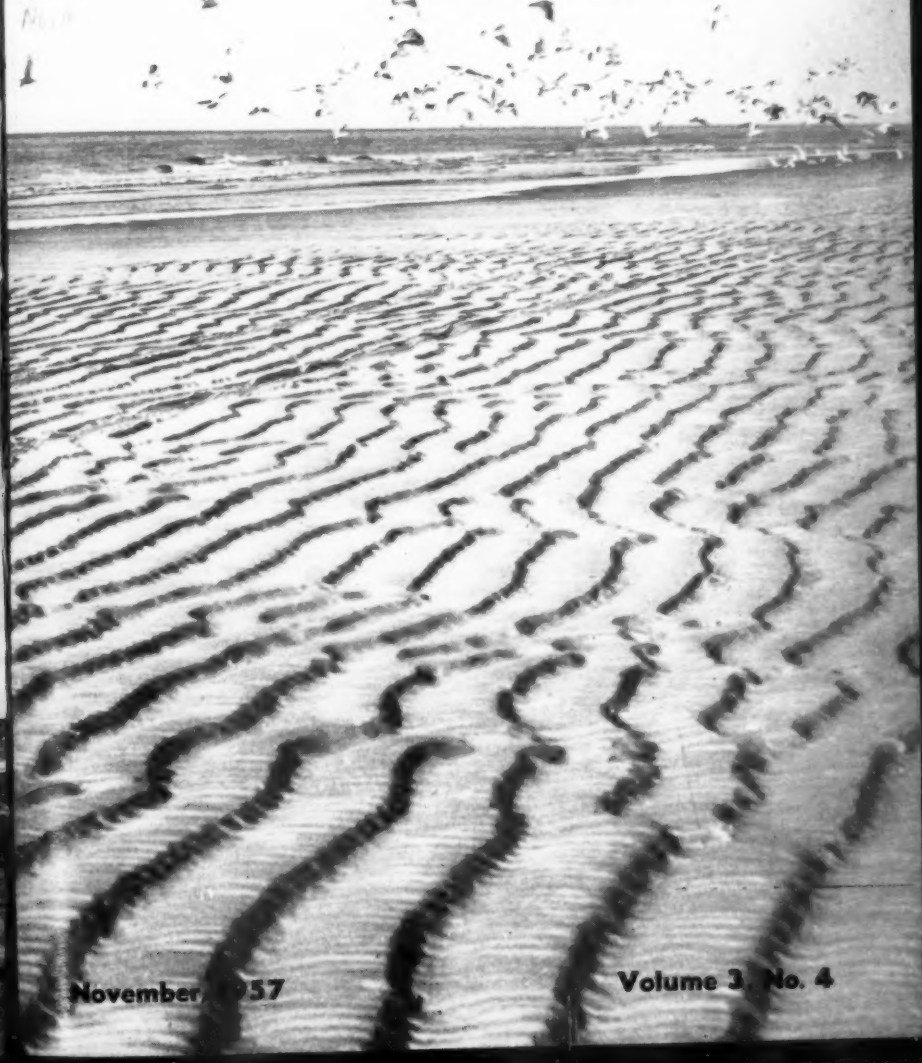
Sea Frontiers

Bulletin of the INTERNATIONAL OCEANOGRAPHIC FOUNDATION



November 1957 Volume 3, No. 4

IT LOOKS LIKE THE ARMATURE OF A DYNAMO, *or perhaps an X-ray of a vertebra, but actually it is a close-up of Cassiopia, a jellyfish which lies on its back on the shallow seafloors of Florida. (Marine Laboratory, University of Miami)*

FRONT COVER. Low tide at Race Point, *Provincetown, along Massachusetts Atlantic coast. Sand and sunlight weave fantastic patterns with the legacy from wind and surf. Swooping sea gulls, however, have eyes only for morsels left by the receding waves. (Massachusetts Department of Commerce)*

BACK COVER. One of Britain's *most famous lighthouses, Eddystone, in the English Channel, near Plymouth, marks the approach to Plymouth Sound, site of one of the world's most famous marine laboratories. (British Information Service)*

SEA FRONTIERS

Bulletin of the INTERNATIONAL OCEANOGRAPHIC FOUNDATION

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Editorial Office: The Marine Laboratory, University of Miami, Coral Gables, Fla.

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Application for second class mail privilege is pending at Miami, Florida.

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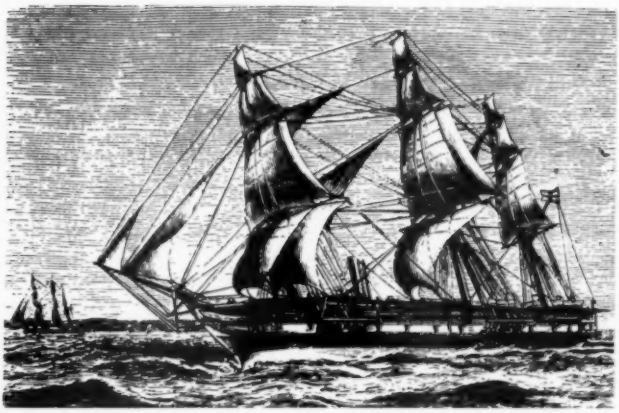

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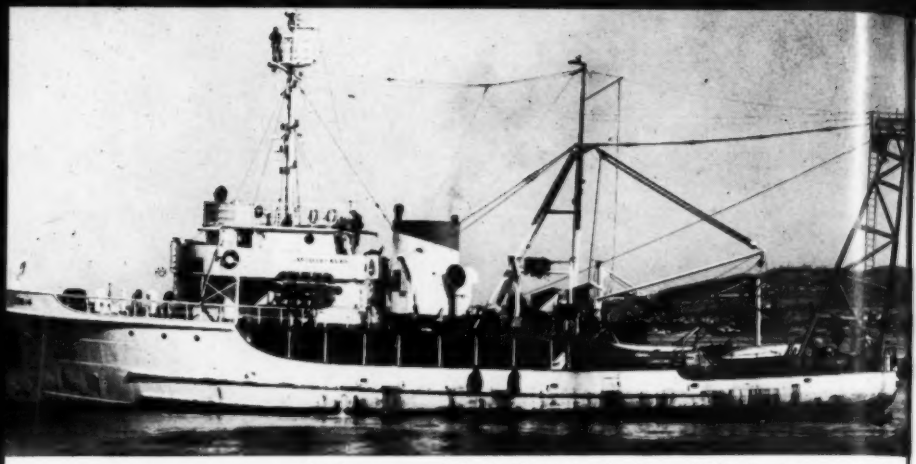


IN CONTRAST WITH *the large especially built research ships of the Soviet, most of the oceanographic vessels of the free world are either old and ready for replacement or else conversions of craft built for other purposes. Typical of the latter is a former tug, operated by the Scripps Institution of Oceanography, La Jolla, California.*

Later Than We Think

PERHAPS the most sobering conclusion to be drawn from the launching of the first earth satellites by Soviet Russia is that the Russians are not an ignorant, unskilled lot. This fact has been known to the scientific world for some time. But the American and European man-in-the-street, deluded by the boasts and claims of Soviet politicians, has assumed that the free world could match or double any accomplishment of "Ivan the peasant."

Yet quietly and behind the scenes, as true scientific research work usually is carried out, the Communist world has been making progress. That it has been assisted by German scientists is beside the point. So, too, have the nations of the free world, including the United States. The hard fact must therefore be accepted that much of the credit for the accomplishment of one of the most spectacular feats in the history of science rightly belongs to the Russian people.

Having accepted this, the free world need not lose itself in despair and bitter recriminations. The fact that the Russians were first to put a satellite into space should serve as a challenge to scientists of the democracies to achieve other goals, in fields perhaps closer to human needs and aspirations.

The earth satellite, after all, is mainly important in its relation to missile warfare, interplanetary travel and the extension of certain geophysical measurements. Its value is partly in the field of destruction and it does not in general hold promise for advancement of a benign civilization ex-

cept in a rather distant fashion. Our bread and butter, coal and oil, and conventional travel are still important. We certainly must continue to improve our walking, even while looking forward to interplanetary running.

Rather, the challenge to free world science today is in other fields, less dazzling perhaps, but, in the long run, of greater benefit to mankind. From the increasing number of reports that are coming from behind the Iron Curtain, Soviet Russia also recognizes the importance, for instance, of oceanographic and marine research, and has already put into operation larger seagoing research vessels than has any other nation. Its submarine fleet is the world's largest.

This is remarkable when it is considered that the Soviet bloc of nations is not separated by large bodies of water, as are the countries of the free world. While the air age has somewhat diminished the historic role of the sea in both war and peace, the ocean lanes will still be the chief carriers of heavy raw materials—some of which are not produced within the Soviet Union, but are greatly needed by the Communists.

The Russians apparently recognize the full importance of many unsolved problems of the sea—such as deep-sea currents, the disposal of radioactive wastes, Arctic research, mysterious deep-sea sediments, and the value of marine fisheries. They are aware that vast amounts of food, minerals and chemicals may be derived from oceanic waters. All reports indicate that the Communists are devoting time, money, and concerted effort to oceanographic research and field work that may soon give the Soviets pre-eminence in this field, as they have in rockets.

Oceanographic research is, in the nature of things, expensive. It requires skilled scientists of specialized experience, and large well-equipped vessels. The vast extent of the ocean (even the top surface covers three-quarters of the area of the earth) precludes any really effective work on a solely national basis. The free world, with its constant exchange of scientific findings and data, has a natural advantage over the Communist bloc in such endeavors provided it can find the funds and equipment to carry on the basic research necessary.

A glance at the map reveals that most of the nations of the free world are separated by vast expanses of ocean. Why not, paradoxically, consider this a bond? The sea and all that it means to mankind might well become a principal interest in democratic scientific endeavor; in other words, that which separates them physically should unite them scientifically.

In the light of recent developments, it should be fairly obvious that not only the scientist, but everyone who believes in democracy and free enterprise, now has a stake in the future of science. Our united effort and support, therefore, are needed to bring scientific research and activity ever more vigorously to the fore, not only in oceanography but in every field of science—*to regain the lead for the free world!*

ONE FISHERMAN *may bring a bluefin tuna to gaff, but it takes the combined efforts of the boat's crew to hoist the big fish on board. Tuna ranging close to a half a ton in weight have been caught in the waters off Wedgeport, Nova Scotia. The angler is Eduardo Reyes C., I.O.F. member from Santiago, Chile. (Nova Scotia Film Bureau)*

Tracking the Elusive Tuna

By F. G. WALTON SMITH

FUTURE DEVELOPMENT of world fisheries depends to a considerable extent upon the solution of one basic problem — when, why and especially *how* do fishes migrate. In other words, what mysterious mechanism (some call it "instinct") prompts certain oceanic fishes to follow the same movements, year after year, and century after century, through the seemingly trackless expanses of the open sea?

And why, for no discernible reason, do they sometimes fail to appear? This, too, worries both anglers and commercial fishermen.

Answers to questions such as these are extremely important. We already

know, for example, that the blocking of rivers for hydraulic power, their pollution by industrial operations, and other man-made interference with the migratory pattern of the salmon has deprived this important food fish of some of the streams to which it is compelled to return for breeding (*Sea Frontiers*. Vol. 3. No. 2).

But this is a small matter when compared to the problems raised by the migrations of oceanic fish, the pelagic stocks of which are distributed over the high seas, and which have an enormous existing and potential value.

Migrants Will Provide Food

It has been frequently said by fishery biologists that the offshore surface-living fishes, which scientists call pelagic, must play a large part in any great future increase of world food production. The bottom living fishes, such as codfish and plaice, are restricted to the shallow banks adjacent to the continents. The greater part of the oceans overlie deep water, where there are no potential bottom fisheries. So, all over the world, fishery exploration vessels are seeking new concentrations of tunas, mackerels and their relatives.

These explorations in mid-Pacific, in the Gulf of Mexico and Caribbean, off South America and Australia, all seek to find food fishes that roam far from land. In order to narrow the search it is necessary to know more about the conditions of temperature, salinity, light and depth, as well as food, which the pelagic fishes prefer. Equally well it is necessary to know why and when they migrate from one place to another or from the surface to an underlying depth. This information becomes especially vital when a new fishery is developed, for then the fishing vessels must be able to forecast the periodic movements of the fish, so as not to waste expensive time and fuel at sea, only to find that the fish have moved.

Fishery Biology Lags Behind

There is another reason why the study of pelagic fish migrations is important. Much has been written about the value to sea fisheries of oceanography, the study of ocean currents, temperatures and other physical and chemical factors. In actual fact, the application of this science to the fisheries, especially to the forecast of fish migrations and of gradual changes in the distribution of fishes has been disappointing. At least it has been a good deal more satisfactory when used for explaining such changes *after* they have happened. The fault does not lie so much with oceanography but rather with fishery biology. The truth is we still do not know enough of the behavior of fishes to be able to use oceanographic knowledge fully and to greatest practical advantage.

The Giant Bluefin Tuna

Among the pelagic fishes, one of the most striking is the bluefin tuna, which grows to be more than 1000 pounds in weight and which migrates over very considerable distances. Although it does not have the spectacular fighting habits of the marlins and swordfish, it is a dramatic sight to see one of these gargantuan mackerels dwarfing into insignificance the anglers, as it is finally brought to boat and manhandled aboard with rope

and tackle. Perhaps that is why anglers from Chile to Canada and from Germany to California have met each year to compete in the International Tournaments at Wedgeport, Nova Scotia. So, the bluefin will serve as an excellent and familiar example in discussing the complicated and difficult problems which the scientist faces in investigating fish migrations.

Warm-Blooded Torpedo

These giant fish are well adapted to their long migratory travels. Efficiently streamlined, well rounded in front and tapering off behind, they are able to travel long distances, at times reaching speeds of 20 knots. This is made possible by their highly developed muscular system. The whole body is jammed with compactly arranged muscles, more like the flesh of a land animal than the light flesh of less powerful fishes.

A special blood supply keeps the muscles supplied with fuel, and greater efficiency is gained by the temperature at which they work. The tuna is not a cold blooded fish, but normally lives at several degrees above the temperature of the surrounding water.

Blind In One Eye!

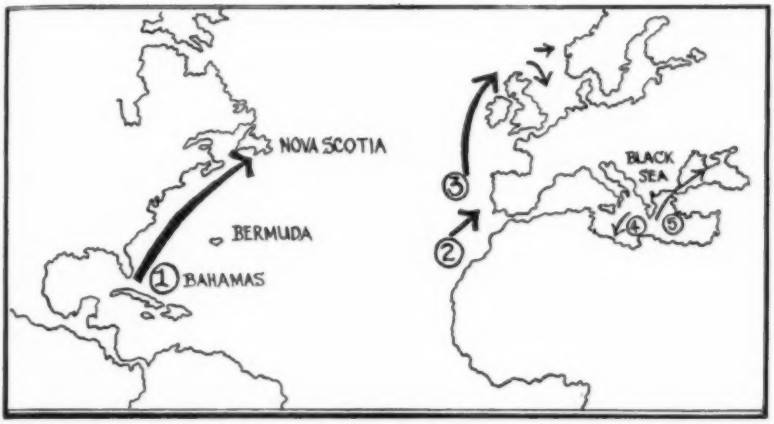
The bluefin is found over a wide area, in most temperate and warmer seas. It has long been known from the Mediterranean, and has been fished commercially since the days of the ancients. In fact, Aristotle described its migrations in the Bosphorus, through which the schools pass in April, to spawn in the Black Sea, returning to the Aegean Sea in September.

Aristotle, incidentally, was probably one of the first to take a scientific interest in their migration. He noted as a scientific observation that they tend to follow the left hand shores during their passage and gave as a probable explanation the suggestion that they are blind in one eye! As we shall see, the migrating habits of fishes are not to be explained away by such a simple mechanism.

Schools of bluefin, like other species of tunas, have the habit of appearing in a given area quite suddenly and with great regularity at certain seasons of the year. After a stay of several weeks or a few months, the schools depart just as suddenly as they appeared. The questions faced by scientists are, whence do they come, where do they go, why do they undertake such extensive movements and what biological mechanism enables them to follow so closely accustomed paths at accustomed times.

Whence and Where?

The questions of whence and where are the simplest to answer, but even so, are surprisingly complex. For instance, the Mediterranean tuna has been observed from classical times by commercial fishermen but information on their movements is still incomplete. Most writers of classical and mediaeval times thought that the giant tunas migrated great distances between the Mediterranean and the Atlantic Ocean. It was believed that they left the Atlantic in spring, passed through the Straits of Gibraltar and moved eastward through the Mediterranean into the Black Sea, where they spawned. Afterwards, at the end of the summer, they returned once more



PRINCIPAL KNOWN MOVEMENTS *of the bluefin tuna are indicated by arrows (1) from the Bahamas to the Nova Scotia feeding grounds; (2) from the southwest towards the Iberian peninsula; (3) from the coast of Spain to the north of Scotland, with feeding schools branching into the North Sea and along the Norway coast; (4) towards the north African coast to breed; and from the Aegean Sea into the Black Sea.*

to the Atlantic. But this is now known to be incorrect.

Several, Not One, Migration

Tuna are now known to be present in the Mediterranean at all times of the year. In the spring they begin to join together in large schools preparatory to spawning. This takes place in a general triangular area bounded by Sicily, at the toe of Italy, and Sardinia and Tunis on the African continent. It is also likely that they spawn at about the same time in the Atlantic, outside the Straits of Gibraltar and possibly in other places too.

Thus what was at one time thought to be a single fleet of tunas moving in a single migration of great extent, now appears to be a number of relatively independent groups, breeding at different places.

It is also known that in summer the bluefins migrate northwards in the Atlantic from the warmer waters off North Africa and Gibraltar towards the mouth of the English Channel. From here they pass west of Ireland, eventually some reach Norway, and others enter the North Sea. With the onset of colder weather they return to warmer waters.

Sensitive to Temperature

Before turning to the bluefin migrations in other parts of the world and especially to the huge stock that annually leaves the Florida Straits on its way to Nova Scotia, we may take a brief look at the causes of the Mediterranean migrations. Why do the schools of tuna appear off Sicily, Sardinia and Tunis, off the Straits of Gibraltar, the Black Sea and as far north as Norway and Sweden at their different appointed seasons?

First of all the bluefins are sensitive to the temperature of the water in

which they live. They will not enter waters which are colder or warmer than their preferred range. These preferred temperatures are roughly from 55° Fahrenheit to 80° Fahrenheit. Thus, in the winter, as the waters cool, they tend to go southward and in the summer northward. Even so, this gives them a much greater freedom of movement than their actual path of migration would suggest. The restrictions of temperature can only interfere with their summer movements when they approach their northernmost limits. This may explain why in some years they appear at a far more northerly place than they do in other years, in response to the year to year temperature changes which are known to exist.

SCHOOLTIME FOR FUTURE ICHTHYOLOGISTS? *These large fishes never fail to excite curiosity, particularly that of children. To make it an even better story, this big bluefin tuna was boated by one of the women contestants on "Ladies' Day," during the week of the International Tuna Tournament, Cat Cay, Bahamas, in 1957. (E. John Long)*

Spawning Schools

It is also clear that the tunas, during the winter, do not form the large schools that they do at other times, at any rate not where they can be seen at the surface and especially near shore. They first begin to appear in large schools at the surface in the spring, perhaps coming together from a wide area to join forces at localities especially suited to breeding and to the survival of the eggs and juveniles. Off the coast of Libya, for instance, they begin to appear in April when the water temperature reaches 65° F and the salinity reaches 38 parts per thousand, somewhat higher than Atlantic Ocean salinities. The large ones appear first and the small ones later.

After spawning has taken place, the fishes are spent and underweight, with shrunken stomachs. Yet now is the time when they undertake their greatest travel. The young adults do not appear to disperse to the extent that the adults do, but all direct attention now to the pursuit of food, travelling generally northward in search of schools of smaller fish. Much the same thing happens in the Atlantic, where the large fish, after breeding off the coast of Spain, move north in a steady purposeful stream until the leading schools reach Scandinavian waters.

Schools arriving at different places vary considerably in size and numbers. One probable cause for this is the fluctuation in temperature from year to year. Not only may this influence the tuna directly but also indirectly by its effect upon the movements of the schools of smaller fishes upon which they feed.

Saltiness of the water is also a probable factor, since even in search of food the tunas will not enter, except briefly, water which has saltness of less than about 35.5 parts per thousand.

Another observation has helped to destroy the old idea that bluefins move in a single great caravan from place to place. This is the fact that young tuna seem to stay close to the coast, after the adults have long passed. Only when they reach a certain age do they begin to join the great spawning and migratory movements.

Anglers Cooperate in Research

Bluefins are international creatures. They are found in Japanese, Australian, South American and North American waters, as well as off the Mediterranean and northern European coasts. It is generally agreed that the tunas from the various parts of the Atlantic and Mediterranean belong to one species, *Thunnus thynnus,* but that the Australian species is a separate one and so is the Japanese. Off the coast of California the bluefin tuna also appears to be a distinct species. But all of them show the same general pattern of schooling in breeding season, followed by feeding migrations to higher latitudes.

All of them, too, are sought by the big-game angler who is therefore in a particularly favorable position to help the investigator of fish migrations by reports of unusual occurrences and by descriptions of the behavior of these powerful fish. Valuable information has already been provided about the western Atlantic bluefin both by anglers and guides.

"Horse Mackerel"

In the western Atlantic the horse mackerel, as the bluefin tuna was called when first fished commercially, was probably named for the resemblance to its mackerel cousins and for the darkened color of the flesh, more like horsemeat than fish, but nevertheless both palatable and tender if properly cooked. Off the coasts of New England and Nova Scotia they have been caught in small quantities for many years.

The smaller and younger "school" tuna have also been known for some time off the Atlantic coast states. But,

A TUNA GOES UNDER THE KNIFE. *The author, about to examine the stomach contents and roe of a newly-caught bluefin at Cat Cay, Bahamas, for further study at The Marine Laboratory of the University of Miami. Science still has much to learn about these big fish, which spend much of their lives in blue water, well off mainland shores. (Bahamas Development Board)*

so far as the fishermen were concerned, the tunas were fish which appeared at a certain time of the year, stayed for a matter of weeks or months and then disappeared. Not until 1933 was anything known about the migratory path which the big ones followed before they reached New England and Nova Scotia.

The origin of the giant tuna, which have been caught by anglers at Wedgeport, Nova Scotia, since 1911, was the subject of considerable speculation. Did they come from the European stocks, migrating clear across the Atlantic, or were they a separate group? If so, what was the path of their annual movements? It was not until after 1930 that the answer was provided, when large bluefins were seen in the Straits of Florida, 45 miles or so from Miami, on the western edge of the Great Bahama Bank. Ernest Hemingway, famous author, angler and member of the International Oceanographic Foundation Board of Trustees, is credited with the first to be caught off Bimini and Cat Cay in 1935.

A Partial Answer is Found

Tuna angling gradually became popular off the Grand Bahama Bank and the annual tournaments at Cat Cay have since yielded more than 100 fish in a three day period, with some fish going well over 700 pounds. Biologists from The Marine Laboratory of the University of Miami have examined these fish with care and have formed a number of interesting clues. First of all, most of them have little food in their stomachs and their roes are in a ripe, or often in a spent, condition. This strongly suggests that they are actively breeding or have just finished breeding. Somewhere, then, about this time and general area the bluefins gather to spawn. They begin to appear in the Florida Straits during the month of May.

By the end of June they have filed by in school after school until the migration is over. Soon after the last schools have passed the leaders begin to appear in the waters off Long Island and southern New England and finally make their way to Nova Scotia.

Some Slim Clues

The story is still incomplete. After a summer of heavy feeding, the fish are now plump and relatively sluggish, but in the late fall they begin to disappear from northern waters. Where do they go? And equally important, whence do they come before they enter the Florida Straits? Because of their breeding condition while off Cat Cay in May, at about the same time as the European tunas are breeding thousands of miles away, it would seem likely that the tunas on opposite sides of the Atlantic live separate lives. The suggestion has been made that Nova Scotia schools make their way across the Atlantic to join their fellows in the warmer waters off Spain and Africa to spend the winter, presumably returning just north of the Equator in spring in time to group for spawning before their northerly journey in the Gulf Stream. Such a long and continuous movement of a single population hardly seems likely.

Other clues have come forward. With the cooperation of the U. S. Coast Guard, observers have flown out

from Bermuda in the late fall seeking for signs of tunas on their return journey. Other planes have been used for spotting the fish in the Caribbean in early spring off the Grand Bahama Bank. The U. S. Fish and Wildlife Service vessels engaged in exploratory longline fishing in the Gulf of Mexico and in the Caribbean have reported tuna catches. Other reports have come from individuals, anglers, airplane pilots and others, who have seen what they believe to be bluefins at places and times beyond the established northerly migratory path.

Submerged Return Passage?

Some of these reports have located the giant tuna off Bermuda in October. Some place them, later, in the Caribbean Sea and in the Gulf of Mexico. Nearly all, however, refer to scattered fishes rather than large schools. Added together they seem to show that, after leaving Nova Scotia in the fall, the schools disperse and the fish swim more or less independently south, keeping to the east of the Gulf Stream and eventually find their way to winter quarters to the east of the Bahamas, in the Caribbean and perhaps the Gulf of Mexico. Quite possibly during the winter they still do not school very strongly and tend to remain out of sight, feeding below the surface, and are thus not detected except when the submerged commercial longline gear is used.

It is clear that only exploratory operations with this gear over a wide area at appropriate times from late fall to early spring will give the final answer. Miles of line with hundreds of baited hooks at 10 to 30 fathoms below the surface are necessary to seek out fish which the surface angler never sees.

THE JAPANESE LONGLINE, *with hundreds of hooks on leaders placed at intervals on a buoyed line, miles long, is still the most efficient method of catching scientific specimens of tunas. This method, developed by the Japanese for commercial purposes, calls for special hauling gear and baskets or tubs in which to coil the lines. The photograph shows the gear in use for bluefin tuna research aboard the Miami research vessel Geronda, in the Straits of Florida. (The Marine Laboratory, University of Miami*

During the winter dispersal bluefin tunas may move out beyond the Caribbean area into the Atlantic Ocean and may even to some extent overlap European tuna extending out from the European and North African continents. A preliminary analysis of the measurements of these two groups by Dr. Robins at Miami shows no significant differences and suggests there is such an intermingling, if not today, at least in the not too distant past.

School Tunas

When ready for spawning, the tunas may assemble in places both north and south of the Bahamas, north of Cuba and other places before again moving north. But the young tunas inshore along the east coast of the United States from Maryland northward apparently do not join the main group until they become mature. Where do they come from?

There is no certain answer, but it seems likely that the young fish are carried north from the spawning grounds into colder waters. In the winter they may merely move offshore

into warmer water below the surface until returning inshore the following year. This is suggested by the behavior of the Mediterranean tuna. Here again the longline exploration is the most likely method of finding the answer.

Biologically How?

The questions of when and where, though still imperfectly answered, have at least been reduced to narrower limits. The wherefore of the migratory movements is likewise partially satisfied by the impelling urges of schooling for breeding purposes, by the need to seek food and by the limitations imposed by temperature and salinity and by the distribution of food fish. But the question of how, the nature of the biological machinery

which keeps the fish to their appointed pathways, has not gone far beyond speculation.

The problem can be stated quite simply. How is a fish able to navigate from the Florida Straits to Nova Scotia in the early summer and back to its winter quarters in the fall? This is as much of a puzzle as the still unsolved question of the navigation of birds in their annual migration, when they travel for days at a time at sea, out of sight of land and with nothing but the sun to provide a guide.

Following the Gulf Stream?

It has been said that bluefins follow the Gulf Stream. But they do not drift passively with it or they would end up, as the Gulf Stream does, clear across the Atlantic, off European shores. Instead, they swim actively and purposefully in a path which eventually leads to New England and Nova Scotia waters.

The truth is that a fish in the middle of an ocean current has no way of telling the direction of its flow any more than a man in a small boat during a heavy fog can tell whether he is drifting towards or away from shore, without the sound of a bell buoy or other fixed objects to give him a fixed point of reference. The direction of tidal flow in a narrow estuary is easy to judge because movements may be seen in relation to the fixed objects on land or stationary channel markers. But the fish at sea has no river banks, no land, not even the sea floor to refer to.

Heading for Cold Water

It has also been noted that the tuna migrates from water at 80° F in the Florida Straits to Nova Scotia waters which are at less than 60° F, and it is suggested that they are simply seeking colder water. A moment's reflection will show the impossibility of any direct temperature control over movement. Fish have been shown to possess an ability to detect and to react to extremely small changes in temperature. But the change of temperature along and across the northward flow of the Gulf Stream, though considerable when the entire path is considered, only amounts to something less than one hundredth of a degree per mile on the average, an amount insufficient to provide a steady continuous correction in the direction of the fish's movement.

A Fish "Sun Compass"

With no assistance from water currents or temperature and with no way of sensing the direction in which the distant schools of food fishes will be found, it seems probable that the general direction of migration may be guided by the signpost of the sun. Although the sun rises in the east and sets in the west, thus constantly changing its position, it has nevertheless been shown that bees have the ability to return to a place previously visited so long as they have the sun to provide direction. Apparently, they are able to take into account its movement during the day. It is not impossible that migrating fishes do the same. They are, at least, creatures higher in the scale of evolution than insects.

An interesting fact which may be related to this is the discovery of a "third eye" in the bluefin. In all ver-

tebrate animals there exists an outgrowth of the upper part of the brain which appears to represent the rudiment of a third eye in the top of the head. This, the pineal eye as it is called, is greatly reduced except in the lampreys and in certain reptiles where it has a recognizable retina and lens.

In the bluefin tuna, and a few other fishes, although no sign of a lens or retina has been found, there is a tubular structure filled with clear jelly leading from this part of the brain to the skin on the top of the head. Most remarkable is that the skin at this point, instead of being dark in color and opaque, is lacking in pigment and permits the passage of light.

Cyclopean Eye, Ages Old

As yet, no evidence is available that the fish is able to sense light through the medium of this pineal tube but farther research into its structure would be of interest. The fact that many migratory fishes do not possess the pineal tube does not necessarily mean that this has no function or part in guiding the migrating tuna, but it adds to the cautious attitude of scien-

IS THE GENERAL PUBLIC INTERESTED IN BIG GAME FISHING? *This aerial view of the crowd that gathered at Narragansett when the cry went out "Tuna's coming in!" should be an answer. Center of attention is the pier where catches are weighed and displayed. Hundreds participate in the various tournaments, for big game fishing is now within the reach of the average angler. (R. I. Develop. Council)*

tists, pending further study and experiment. Meanwhile it is at least interesting to note that the bluefin's "middle eye," even if non-functional, has a very respectable antiquity. The very first fishes, armored creatures living in the silurian seas over 300,000,000 years ago, had a well developed middle eye.

Obviously, the mechanism of biological navigation in fishes presents parallel problems to those of birds. Only when this is better understood can oceanography provide its fullest assistance to fisheries. A case in point is the forecast of yearly changes in the fishery at Wedgeport. Whereas at Wedgeport, Nova Scotia, in 1949, 72 fish were landed in three days of competition, the catch has dropped in recent years to one or two.

MOST OF WHAT WE KNOW *about baby tuna has come up in the plankton nets. This bottle of fuzzy debris sieved from the sea will be carefully examined in the laboratory. There is always the possibility that it will contain infant bluefins. (The Marine Laboratory, University of Miami)*

For Future Investigations

In the absence of a detailed and elaborate scientific study of the area, involving fish and plankton surveys, and investigations of changes in temperature, salinity and ocean currents, one may only speculate on what happened to bring this about. The most likely possibility suggested is that temperature changes have altered the distribution and behavior of the smaller fishes serving as food for the tuna, or have directly affected the behavior of the tunas themselves.

Even Distant Winds Interfere

The warming up of the north Atlantic and subpolar waters in recent years has had a marked effect upon bottom living codfish, sending them far north of their earlier range. This could be having its effect at Wedgeport. Oddly enough, though the Gulf Stream is a carrier of warm waters from equatorial regions to the north, yet a slowing down of the Gulf Stream might increase the northern spread of warm waters instead of cooling them. This happens because the warm surface water of the central north Atlantic, bounded by the Stream, is piled up, due to the earth's rotation,

CLOSE-UP OF A BLUEFIN TUNA *brought to gaff in the Gulf Stream. This fine specimen was caught by Señor Rene Villega, of Cuba, during the International Tuna Tournament, which was held at Cat Cay, Bahamas, in 1957. All of the fishes caught here undergo careful study at the hands of Miami ichthyologists. (John Mahony)*

as the Stream speeds up, but spreads out northbound when it slows down. Since the stream is set in motion by winds, including northeast trades in lower latitudes, changes in these winds could have their effect upon the International Tuna Matches in Wedgeport, thousands of miles away.

Attention, Anglers!

These problems will some day be solved. In the meantime, scientists working on these fishes are appreciative of any reports they receive from anglers regarding the behavior or new records of the occurrence of the bluefin. Many such anglers will be at the International Oceanographic Foundation Game Fish Conference in Miami this year. It is hoped others will join in this cooperative work. It has a far wider value than might at first appear. What is found out about tunas at Bimini, Cat Cay or off the coast of Maine may well solve similar problems at the other ends of the earth, in Australian, Japanese or South African waters.

MAMMOTH HYDRAULIC SUCTION CUTTERS *such as this make short work of channel digging and harbor enlargement. Conservationists feel they should have a voice in the planning of such operations, particularly when they affect the habitat of shellfish or small plankton feeders which are links in the food chain, and thus related to the abundance of certain game fish species.*

Coast Waters in Danger

By PAUL E. THOMPSON,
Assistant Chief, Fishery Biology,
U. S. Fish and Wildlife Service

LOOK AT A large scale map of the coastline between Currituck Sound, North Carolina, and the Mexican border. The bays, sounds, bights, intracoastal waterways, estuaries, the sheltered waters behind barrier reefs and islands, and the adjacent marshlands with their salt or brackish ponds form a most complex web of living conditions which are of great importance to marine life and the human community.

Better still, fly over that coastline. You will see, here and there, breaks in the web that are so new, map makers have not had a chance to catch up with them.

The towns and cities are bigger,

the highways wider, the stacks of industry higher, the sea walls longer, and the bulldozers busier. Population and prosperity are twin pressures busily at work on the periphery of the continent.

In the Wake of Progress

Perhaps progress never has been an unmixed blessing. There have been temporary dislocations of people, not so temporary misuse of our streams and rivers as sewers, and long-range damage to our top soils by mismanaged land, for instance. But at our present stage of enlightened development, of greater awareness of life processes, and of greater knowledge of interdependent causes and effects in nature, we should not repeat mistakes of the past without at least being aware of what we are doing, what will be the ultimate cost, and at least minimizing the damages and dislocations left in the wake of progress.

We know a good deal about inshore coastal waters and the marshes that drain into them, and we are learning more about them all the time. This is not boasting, for our ignorance is still colossal about the interrelationships of biological organisms and the physical features of their environment. But we do know enough to recognize that river diversion and marsh drainage will affect the amounts of nutrients brought from the land to the fringe of the sea. We know that oysters, clams, crabs and shrimp and many of the most important fish are utterly dependent upon the inshore waters during *variable* parts of their lives for shelter, food,

THIS IS THE PRIMEVAL MARSH. *Muskrat houses rise from a tidal area not far from Cambridge, Md., where the water table and the balance of nature have not been disturbed. In addition to being animal and bird refuges, such regions are also fish "nursery grounds." But with the growth of the human population, wildlife is often forced to give way before real estate development. (U. S. Department of the Interior)*

WHEN MIAMI DUG GOVERNMENT CUT, *to give sea-going vessels access to its harbor, it carved Biscayne Bay in two, biologically speaking, and erected spoil banks which are now islands (on the left.) However, in time nature adjusts itself to such major geographical changes, and anglers now find no lack of good fishing, even along the banks of the Cut. (Miami News Bureau)*

spawning, and for early life stages.

We know also the importance of water currents to the fate of passive planktonic organisms—the larvae of the invertebrates and fish, and the microscopic plants and animals upon which they feed. We know that temperature, salinity, turbidity and bottom type are critical, and that only slight changes in any one of these may affect the well-being of both fish and shellfish. We are aware that space in nature tends to be fully utilized and shrinkage of available space must increase competition, predation, disease and parasitism, and thus reduce total productivity.

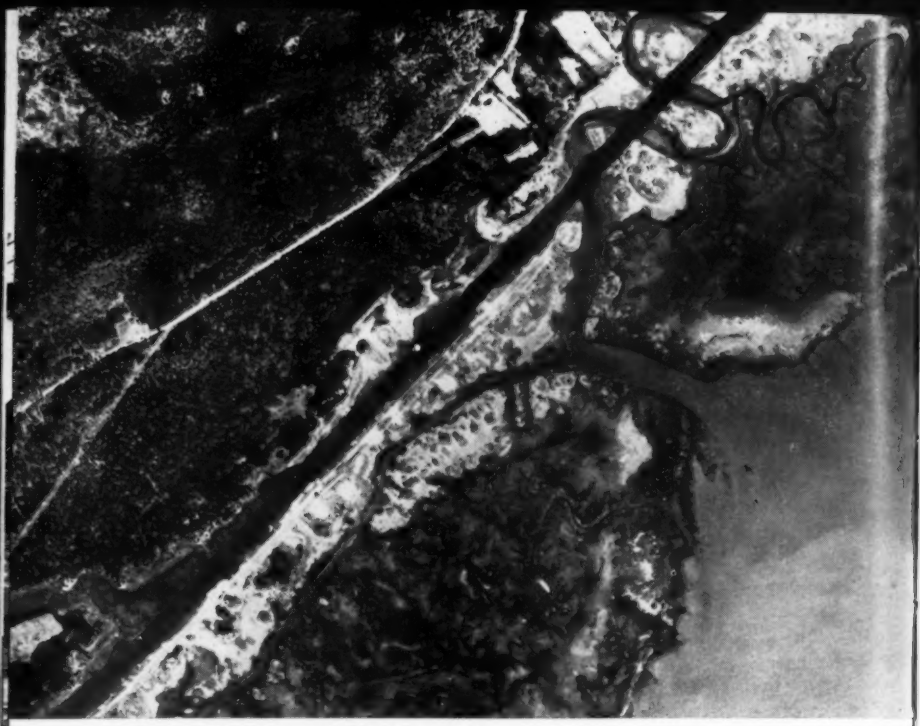
Everyone should be concerned with the habitat of shellfish and the nursery grounds of menhaden, redfish, black orum, sea trout, croakers, spot, striped bass, mullet, snook and sea catfish. There are others, too, like the anchovy, plankton feeders which are links in the food chain, and thus important in the abundance of certain gamefish species.

Changing the Face of Nature

What is really happening to this habitat? Is it something bad? If so, what can be done about it? Let us look at some of the projects already started or proposed for the near future.

Agricultural interests in South Carolina want to withdraw water from the Edisto River and impound it for irrigation. In about the same area, several major river diversions are planned to improve military base water suplies. These changes will reduce runoff, change the extent of tidal action through marshes and in coastal streams, and perhaps have other effects.

A comprehensive Central and Southern Florida Flood Control Proj-



CUTTING DIAGONALLY ACROSS *the marshlands bordering the South Carolina coast, a waterway is a disturbing influence on all the natural marsh life of this area, near the Cape Romain National Wildlife Refuge. (U. S. Department of the Interior)*

ect is in progress which will regulate Lake Okeechobee discharges through the Saint Lucie River to the east and the Caloosahatchee River to the west. Also being considered as a part of the whole project is development of a combined reservoir-floodway zone in the upper St. Johns River basin, with canals and diversions to carry off high waters to the sea above the mouth, and flow and flood control in the Kissimmee River valley, the Everglades, and the lower east coast.

Real Estate Developments

Hydraulic filling, as in sections of Biscayne and Boca Ciega Bays of Florida, for real estate development, is proceeding or proposed in other parts of the coast. Two new causeways are to be built across Biscayne Bay in the Miami area.

Vermilion Bay, Louisiana, is being considered for modification, to convert it into a freshwater lake.

Brackish Sabine Lake and its influence on the adjacent waters on the Texas-Louisiana boundary will be markedly changed if proposed construction of four major dams above the lake are constructed to control flow, reduce siltation and abate pollution.

Modification of the Barataria Bay waterway to make a channel 12 feet deep and 125 feet wide is beyond the preliminary survey stage.

Another Louisiana proposal is for extensive canal construction in the Bayou LaFourche area, plus bayou enlargement.

Industrial Sites in Texas

A deep water navigation channel from the Gulf of Mexico to Corpus Christi and nearby ports, enlarging the 30-mile long channel from 250 feet to 400 feet wide and from 34 feet to 36 feet deep in the Port Aransas-Corpus Christi section is being studied. The proposed channel extensions "would make large acreage of undeveloped land adjacent to deep water available for industrial development."

These, of course, are just some representative examples of "progress-in-the-making" we may live to regret if they are not carefully planned and executed. I have not attempted a listing of inland projects underway or proposed which may influence the well-being of the downstream coastal marine resources, but there are many of these—impoundments, diversions, and industrialization.

Opening Gates to Pollution

It is not a new problem. If we can profit by experience at all, we should hark back to the watershed and estuarine practices in New England, which have made the Atlantic salmon a rare fish. Or to the removal of the guard locks from the Albermarle and Chesapeake Canal in 1918, permitting entrance of polluted, turbid water into Currituck Sound from Norfolk Harbor, exterminating plant life in the Sound and destroying its value for fish and wintering waterfowl. Or to

FARM IRRIGATION AFFECTS THE SEA. *Inland irrigation projects, by removing some of the heavy flow of water that once poured through Hillsborough Inlet, Florida, have caused the partial silting up of the Inlet's mouth. A pile-driver is working on a sea wall to protect the inlet from sand-carrying shore currents. Pompano Beach is at upper right. (Pompano Chamber of Commerce)*

the horrible land-use practices which have ruined many fine streams and rivers. Or to the Delaware River, which for years has been a national pollution scandal.

One proposal for relieving the developing situation has been for the establishment of refuges or sanctuaries at intervals along the coast for the protection of fish "nursery grounds," somewhat similar to the highly successful waterfowl refuges along the flyways.

This is in many ways an appealing proposal, but upon analysis, severe limitations become obvious. The refuge itself could be ruined by developments in contiguous areas. Even if this did not happen, any refuge system could maintain only a very small, perhaps insignificant portion of the total productivity potential of the entire area.

Nothing less than protection from impairment of all the remaining inshore environment should be the aim of conservationists and fishermen. This will take legislation, research, money, imagination and some of that eternal vigilance Thomas Jefferson warned us about.

Broad legislative authority is needed so that State conservation agencies may control what is done in their inshore waters. Money for research could come from salt water fishing license sales; several States feel the time is right for anglers' licensing and are moving for it now. Imagination can come from researchers and conservationists, and vigilance will be a concern of all who realize the importance of these waters to the economy and to the total productivity of the sea. Research is needed at the ocean borders as well as in its broad deeps.

Ocean Not A "Melting Pot"

FISHES keep to their own sides of the sea. The Smithsonian Institution has received a collection of more than 1,000 specimens of Liberian fishes, mostly from salt and brackish waters. It contains many species and varieties not represented in the national collections, but its particular interest is in the differences it shows between the sea creatures of the eastern and western Atlantic.

Superficially they may be quite similar. When studied, however, they are found to represent quite different types. Thus, an ocean turns out to be far from a "melting pot," possibly because for many coastal fishes there are no Atlantic stepping stones.

FLAGSHIP OF THE NARRAGANSETT MARINE LABORATORY *of the University of Rhode Island is the 76-foot R/V* Seahorse, *equipped to carry out any type of oceanographic research within nearby coastal waters. Here the* Seahorse *is shown at the town dock, Wickford, R. I.*

The Narragansett Marine Laboratory

By ROBERT J. CONOVER

Assistant Professor of Marine Biology, University of Rhode Island

IN 1524 VERRAZANI wrote of Narragansett Bay: "... upon entering it, the extent between the coast and the north is twelve leagues and then enlarging itself it becomes a very large bay, twenty leagues in circumference, in which are five small islands, of great fertility and beauty, covered with large and lofty trees. Among these islands any fleet, however large, might ride safely without fear of tempest or other dangers." He goes on to describe the "pleasant hills" surrounding this bay, the "many streams of clear water" entering it, and the geographic features which make it easily defended, but apparently Verrazani did not recognize the extreme fertility of these waters so generously endowed with other aesthetic and material virtues. The quahog or hard clam alone provided 1.9 millions of dollars in revenue to the fishermen of the state during 1955 and the total commercial catch landed at Rhode Island ports has been worth over four million dollars in each of the last three years. No other comparable area on the east coast of the United States with the possible exception of Chesapeake Bay can boast of such wealth in marine resources.

Research Vessels

On the western shore of Narragansett Bay, just opposite Conanicut Island, is located the Narragansett

Marine Laboratory of the University of Rhode Island (hereafter referred to as NML). The offices and laboratories are presently housed in a fourteen-room, pre-revolutionary stone building with a colorful history of its own and a smaller frame building containing a sea water table and aquarium facilities. The Laboratory owns the 76-foot R/V *Seahorse*, equipped to carry out any type of oceanographic research within nearby coastal waters. In addition, it charters a 40-foot, all-steel dragger and an 88-foot oyster boat for work on special projects. One other vessel, a 36-foot LCVP, is on loan from the Navy. Docking facilities are suitable for vessels over 100 feet in length, drawing up to 16 feet. A small boat basin provides adequate protection for laboratory skiffs.

The history of NML began with the appointment in 1934 of Dr. Charles J. Fish to the faculty of the then Rhode Island State College. Shortly after his arrival, a survey of starfish populations in Narragansett Bay was organized with the cooperation of the State Division of Fish and Game. In 1937, quarters for the original staff of five were obtained at Ft. Kearney, a deactivated Coast Defense installation adjoining the property on which the Laboratory presently stands. However, this first permanent home was destroyed in the '38 hurricane. The frame building in use today was erected in 1940, safely above the level of hurricane surges. In addition to the starfish studies already mentioned, NML investiga-

PHYTOPLANKTON IS FOOD *for the hard clam* (Venus Mercenaria). *Dave Pratt is closely examining a fresh sample from the Bay.*

tions during the pre-war years included a study of the biology and seasonal migration of the winter flounder *(Pseudopleuronectes americana)*, the role of coastal salt ponds in the biological economy of Rhode Island waters and the development of a new fishery based on the black quahog *(Cyprina islandica)*.

From High Seas to Brackish Ponds

When the Laboratory was reactivated in 1948, an enlarged three-phase program was envisioned. Not only would the Laboratory continue to aid the State in the solution of its marine problems, but with an increase in facilities and in the size of its staff, a program of basic research and a graduate curriculum leading to a Master of Science Degree in Biological Oceanography could be initiated. The present staff of 22 includes biological, physical and geological oceanographers, as well as research assistants, administrative personnel and a boat crew. In addition, the Laboratory has enlisted the aid of University faculty from the Departments of Zoology, Botany, Geology and Physics for some of its investigations and to assist in the instruction of its graduate students.

Today, Laboratory scientists are engaged in oceanographic studies in the surface waters and on the bottom from the high seas to brackish coastal ponds. Four of the current projects are supported by the Office of Naval Research and the others are State supported. A brief review of some of the work being done by NML personnel should serve to illustrate the scope of our activities.

Animal Plankton of the Open Sea

Marine scientists know next to nothing of the cycles of life in the open ocean. Some observations have been made from research vessels in the course of the occasional oceanographic cruise, but who can say how the changing seasons affect the organisms from day to day and week to week in the vast areas of sea far removed from any land influence.

In 1947 an international weathership program designed to supply a more extensive meteorological coverage was launched through a United Nations agreement. Weatherships are confined to permanent stations in the open ocean, cruising slowly back and forth because the waters are too deep for anchoring. If these ships are to be collecting weather data the year round, why could they not make some routine oceanographic observations and collections as well?

Weekly Collections

Just such a program was started in 1949 by Dr. Fish. Weekly collections of the tiny plankton organisms, so important as food for higher forms of ocean life, were made at two of the U. S. Coast Guard weather stations and returned to NML for analysis along with salinity and temperature observations made at the same time. Since one station was in the cold waters of the Labrador Sea and the other in the warm waters east of Bermuda, a heretofore impossible comparison of open ocean productivity under very different conditions of existence could be made.

Another phase of Dr. Fish's work has been an attempt to evaluate the

LABORATORY SCIENTISTS STUDY *fouling growth at different depths. Don Zinn and Hal Berkowitz are making their weekly observations from the laboratory dock.*

importance of so-called transition zone plankton — the small animals which normally inhabit the water from 250 to 1000 meters below the surface during the daylight hours, but which come to the surface in enormous numbers at night.

At one time the depths of the

ocean were thought to be dark and quiet, but the use of underwater listening gear to seek out enemy submarines during the last war revealed, far from complete silence, an almost continuous, cacophonous chorus of squeals, shrieks, grunts and whistles presumably produced by living marine creatures. Marie Poland Fish, wife of NML's Director, is presently trying to unscramble this underwater confusion of sound by means of hydrophone interviews with representative marine creatures from many parts of the world. Not all marine animals appear capable of sound production, but to date about 200 tropical and north temperate species of fish have had their voices recorded.

Other Sea Creatures Tape Recorded

In addition, the comments of about 20 species of crustacea and several marine mammals have been tape recorded. Not only will this permanent library of marine sounds be useful for the perfection of anti-submarine listening devices, but it is also a possibility that commercial fishes can be sought out and captured by means of their characteristic sound.

Another group of NML scientists under the supervision of Dr. Frank T. Dietz is interested in underwater sound, but in this case it is the scientists themselves who make the noise. Acoustical energy is produced by the detonation of TNT charges under water and the transmission of this sound in the water and in the bottom sediments is then studied with suitable electronic recording devices. Ultimately this type of sonic analysis may be used to describe the type of sediment and we may even be able to learn something about the nature of the rocks beneath the sediment.

Ship Bottom Fouling

Almost every one recognizes the necessity for research into the causes and prevention of fouling incrustations on ship bottoms, wharf pilings and the like, but objects submerged to greater depths are also quickly colonized by a variety of plants and animals. In addition to their direct economic significance as fouling organisms, these deeper - water forms doubtless have an important role to play in the support of marine groundfish populations. Dr. Donald J. Zinn and Dr. Richard D. Wood of the University of Rhode Island Biology Departments with the aid of Harold Berkowitz of the NML staff are presently studying these organisms and the conditions controlling their growth.

As part of the Laboratory's program the possible use of ultrasound in the prevention of fouling growth is being investigated.

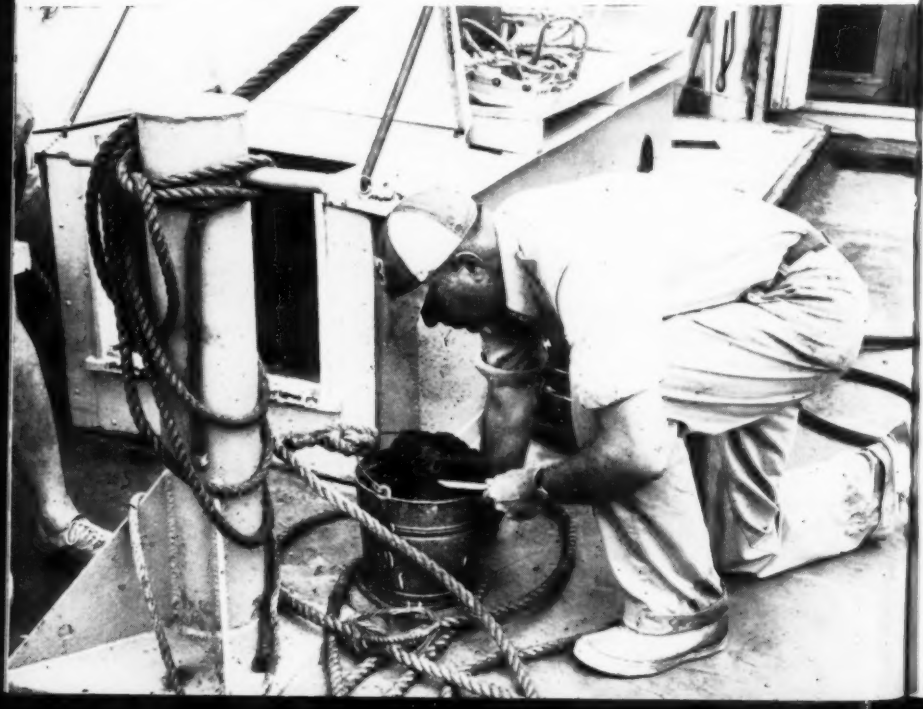
Food Production on the Sea Floor

In Narragansett Bay, the hard clam or quahog *(Venus mercenaria)* is the most important organism of its size found on the bottom. The economic importance of this beast to Rhode Island's commercial fishery has already been emphasized.

For several years Dr. David M. Pratt has been studying the distribution and growth rates of this animal in Narragansett Bay. His investigations have shown that two of the most important factors controlling

the rate of quahog production are the composition of the bottom in which the animal lives and the abundance of its food supply which is thought to be largely composed of microscopic plankton plants called diatoms. Dr. Pratt has shown that quahogs grow up to 100 per cent faster in sandy sediments than in finer sediments containing a high percentage of silt and clay. At the present time, major attention is being devoted to the animal's food supply and the environmental factors which cause it to be particularly abundant in certain parts of the Bay while relatively scarce in other locations.

DR. DONALD J. ZINN, *one of the scientists attached to the Laboratory, makes a preliminary examination of one of the boxes used to collect fouling organisms. Research into the causes and prevention of fouling incrustations on ship bottoms is an important project.*



Salt Pond Investigations

Along the southern shore of Rhode Island are numerous enclosed or partially enclosed bodies of brackish water called "salt ponds" by the natives. Certain of these ponds are important producers of shellfish, particularly oysters and scallops, and serve also as nursery grounds for fin fishes. On the other hand, there are outwardly similar bodies of water which are essentially barren of marine crops. Two contrasting ponds, one highly productive and the other relatively poor in commercial resources, have been the subject of an intensive investigation for the past two years under the direction of Dr. Robert J. Conover.

In addition to the routine collection of the plant and animal inhabitants, attempts are being made to correlate the abundance and production rates

of living organisms with a variety of physical and chemical factors. It is beginning to appear that the most important requirement for a generous production of useful animals is a proper balance between the amount of fresh water entering the ponds from the land and the amount of exchange with waters of higher salt content offshore. Because of their limited size and largely landlocked character, these salt ponds may well lend themselves to human management, perhaps even "sea farming," if sufficient information concerning their biological economy can be obtained.

The Flounder Fishery

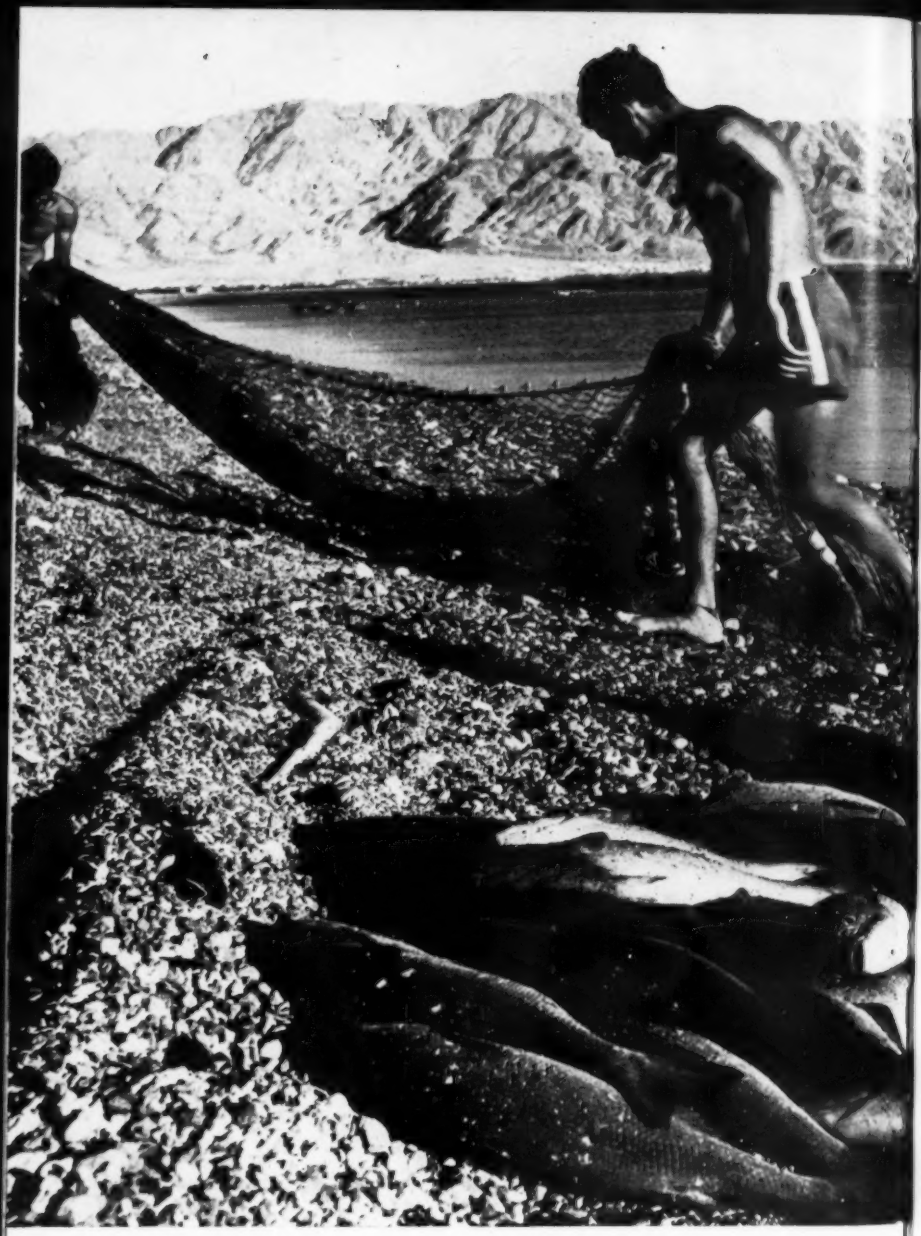
Dr. Saul B. Saila is presently interested in the role of the salt ponds as breeding and nursery grounds for the winter flounder, one of the main supports of Rhode Island's commercial dragger fleet. Dr. Saila is interested in learning to what extent the flounder exhibits "homing instincts" toward the pond of its birth and whether certain environmental variables in the nursery pond might produce certain detectable structural or functional differences which could be used to identify the specific fish stocks after they have left the ponds to join the commercial fishery offshore.

In addition to these long-term projects, NML scientists are frequently asked to give aid or advice concerning specific problems. Recently two of our staff, Professor Steacy D. Hicks and Dr. Robert L. McMaster, have been working with the U. S. Army Corps of Engineers to determine the feasibility and possible detrimental effects of proposed hurricane barriers in Narragansett Bay.

The Narragansett Marine Laboratory is looking toward a bright future. Unlimited expansion is not the goal, but a steady improvement in the quality of the research and educational facilities is anticipated. Plans are now under consideration for reconditioning and modernizing the stone laboratory, and perhaps in the not too distant future, a new wing will add much needed space. Educationally, the graduate curriculum is being strengthened by the addition of new personnel and it is hoped that soon the Ph.D. in Oceanography may be offered.

Estimating the Variables

YACHTSMEN, and others interested in the winds and currents of Florida-Bahamas waters for the southern circuit ocean races during the 1957-58 season, will be pleased to know that a revised edition of the pamphlet "Estimating the Variables" is available. Prepared by the Oceanography and Meteorology staff of The Marine Laboratory, University of Miami, it is available to members without charge by writing to the Foundation.



COASTAL FISHING AT ELIAT. *Once entirely in Arab hands and rather primitive, such activity now is carried on with both shore nets and long lines. Jewish fishermen began coastal fishing in 1949, and now work in teams with Arabs. (Israel Office of Information)*

Israel's Salt Water Fisheries

By SAUL B. COHEN

A MODERN MIRACLE of the loaves and fishes is taking place in Israel. For "loaves" substitute Israel's intensive citriculture and market gardening. Fishes are still fishes, just as they were in Biblical times, but the methods of taking sea food, and the range of Israel's operations, have been greatly expanded. In recent years, quantity as well as quality of the catches also has improved through the use of deep-sea trawlers and net trawling in Mediterranean waters far beyond those bordering Israel itself.

What has so stimulated Israel's modern fishing industry? There are several factors, including an accessible coastline facing the Mediterranean, a population accustomed to fish in its diet, and the Arab blockade of Israel's land boundaries, cutting off beef and other foodstuffs.

Deprived of Some Waters

At the same time, the continuing tension between Israel and its Arab neighbors has stunted certain marine activities, because of limitations imposed upon Israeli fishing near Arab territorial waters. Political and military events have for many months almost precluded fishing in the southeastern Mediterranean and in the Gulf of Aqaba, although the situation is improving in the latter.

Of the four great marine basins that make up the Mediterranean, the easternmost or Levantine is the stage for Israel's chief sea activities. However, this basin has several disadvantages for commercial fishing. First, most of it is 6,000 to 10,000 feet deep. At such depths, far below the continental shelf, light never penetrates, temperatures are low, and the plankton on which fish feed is scarce. Also the technical difficulties of fishing are great.

Excess Surface Salinity

Transitional water layers, 4,500 to 2,000 feet deep, are similarly poor. Fishing is therefore restricted to surface waters, with depths down to 300 and 600 feet, and the upper parts of the intermediate layers.

Other factors curtailing plankton are: high surface-water temperatures, lack of phosphates and nitrates (there are few large perennial streams to bring soluble salts to the sea), and absence of upwellings and over-turnings in the surface and sub-surface waters. Finally, excess surface water salinity (over 39 parts per thousand, compared with 35 parts for ocean waters) limits many species of fish.

There are, of course, favored areas for fishing within the Eastern Mediterranean. These are the broader banks and shallower waters off the coast of the Sinai Peninsula and off the Turkish coast, southwest of Iskenderon. The coastal waters, too, are fairly rich in fish, for lower salinity

and the presence of soluble minerals from local streams provide these waters with richer plant life.

Israel's Need for Fish

This is the environment to which Israel's sea fishing industry must adapt itself. Expansion of modern fishing over the past eight years has been induced by necessity, for the country's food supply is short on protein. Prospects for large-scale expansion of livestock raising are poor, because intensive citriculture and market gardening can be more favorably adjusted to the climate and soils. Former sources of meat supplies, within neighboring Arab countries, have been cut off by the Arab blockade. Israel's meat must therefore largely be imported from East Africa, the Americas or Australia.

Not As Many Sources

The alternative protein, other than dairy products, is fish. Prior to the establishment of Israel, Palestinians were accustomed to look to sea food as a less expensive substitute for meat, and had come to expect fish in plentiful quantities and at reasonable prices. Pre-1939 annual Jewish consumption of fish per capita in Palestine was 26 pounds; the Arab consumption 4.6 pounds.

Today more fish are required because of an increase in per capita consumption by both Jews and Arabs. In 1954-1955, for example, fish consumption in Israel was about 28 pounds per capita for the entire population (as compared with 11 pounds per capita for the entire population of Palestine in 1939). The increase in consumption of fish would have been higher but for governmental restriction of imports.

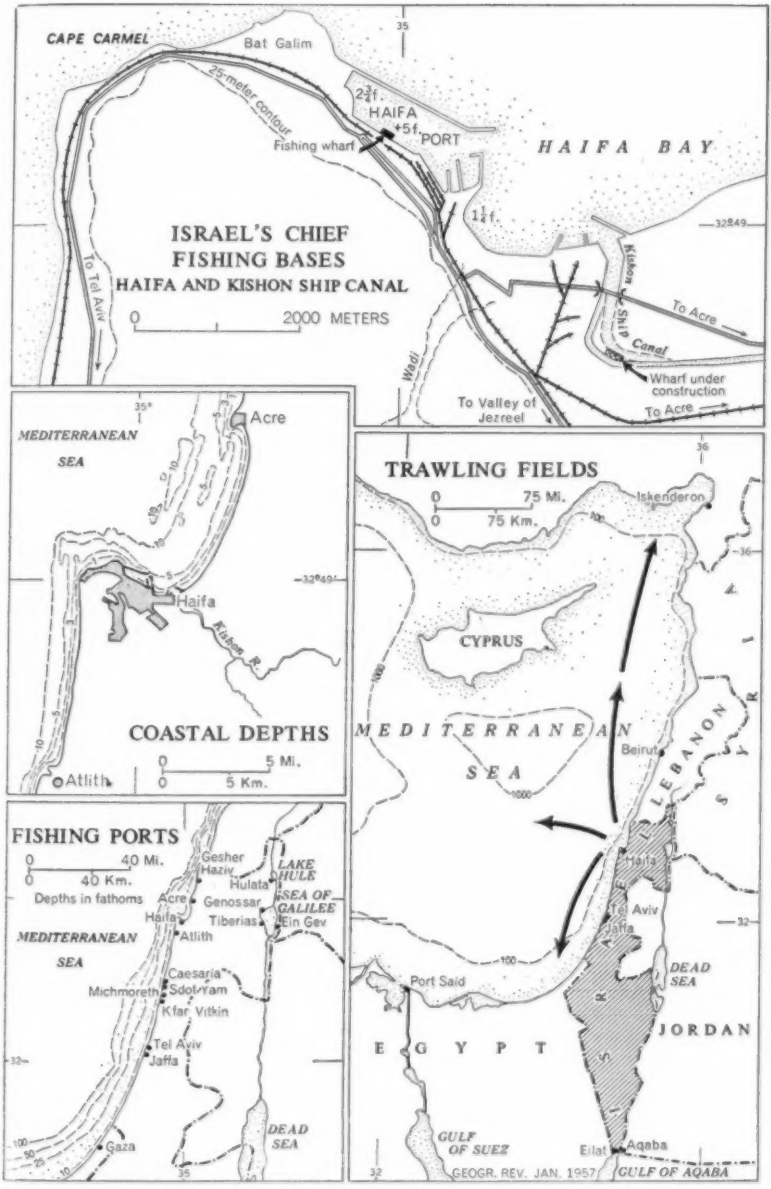
MODERN ISRAEL'S FISHERIES *are increasing in importance as new vessels extend their activities not only into the Mediterranean Sea but the Gulf of Aqaba as well. The map shows also how Israel is enveloped by Arab neighbors, who have cut off former meat supplies. (Courtesy of* Geographical Review, *American Geographical Society)*

Another factor to be considered is the disappearance of many sources of fish supply readily accessible during the British mandate. Then Palestinian fishermen caught about 35 per cent of the total fish consumed. The remainder was imported, but mainly from nearby waters. In 1944, for example, the Palestinian catch of 1,800 tons from the Mediterranean Sea was supplemented by imports of 5,000 tons, the majority coming from Egyptian, Syrian, Lebanese and Jordanian (the Gulf of Aqaba) sources. Some came from Italian trawlers operating off the Palestine coast, and the remainder from the North Sea. Fish farms produced 600-700 tons and lakes 450 tons.

Arabs Were Small Operators

Most Palestinian fishermen were Arabs, engaged in small coast-hugging operations. But during the Israel-Arab war the bulk of this group fled from the country. The economic blockade imposed on Israel by the Arab League has stopped imports from Egypt, Syria and Lebanon and has severely restricted Israeli fishing in the Eastern Mediterranean.

Since Israel now imports more than half of its total fish, it must make pur-


CAPE CARMEL
Bat Galim
25-meter contour
HAIFA
+5f.
PORT
Fishing wharf
HAIFA BAY
ISRAEL'S CHIEF
FISHING BASES
HAIFA AND KISHON SHIP CANAL
0 2000 METERS
To Tel Aviv
Wadi
Kishon
Kishon Ship Canal
To Acre
Wharf under construction
To Valley of Jezreel
MEDITERRANEAN SEA
Acre
Haifa
Kishon R.
COASTAL DEPTHS
0 5 Mi.
0 5 Km.
Atlith
TRAWLING FIELDS
0 75 Mi.
0 75 Km.
Iskenderon
CYPRUS
MEDITERRANEAN SEA
Beirut
LEBANON
SYRIA
Haifa
Tel Aviv Jaffa
DEAD SEA
Port Said
JORDAN
EGYPT
GULF OF SUEZ
Eilat
Aqaba
GULF OF AQABA
FISHING PORTS
0 40 Mi.
0 40 Km.
Depths in fathoms
Gesher Haziv
Hulata
LAKE HULE
SEA OF GALILEE
Genossar
Tiberias
Ein Gev
Acre
Haifa
Atlith
MEDITERRANEAN SEA
Caesaria
Michmoret
Sdot Yam
Kfar Vitkin
Tel Aviv Jaffa
Gaza
DEAD SEA
GEOGR. REV. JAN. 1957

chases much farther away. This has raised the price to the domestic consumer and put a strain on government foreign-currency outlays. Israel spends two million pounds sterling annually for imported fish, including fillet, fresh and canned, and nearly the same amount in domestic currency as subsidies to retailers. These expenditures are over and above the subsidies and foreign currency outlays that are currently being made to maintain and expand the domestic fishing industry.

Major Categories of Fishing

A great deal of attention has been paid to the improvement of the domestic fishing industry, the only practical alternative to importation. The sources of supply are two: salt water and inland waters.

The main attention of this study is directed toward Israel's salt-water fishing industry. This is not because the other source is less important. On the contrary, at present pond and lake fisheries account for more tonnage than the sea. However, more has been written on Israel's inland-water fishing, especially fish farming; its sea-fishing industry has remained relatively unnoticed. Moreover, salt-water fishing has significant geopolitical implications because of the contacts that must be made with other Mediterranean countries. Most important, it is to the open sea that Israel's fishing experts look in their plans for long-range expansion, for fish pond expansion is limited by the competition of farm crops for water and good soils.

Of the major kinds of salt-water fishing—surface and coastal, deep-sea trawling, and long-distance banks—deep-sea trawling ranks first. In 1954-1955 it accounted for 1,850 tons of fish, an increase of 43 per cent over the take in the preceding year. Trawling is carried on in the surface and intermediate water layers at distances of 4 to 20 miles off-shore.

Although the trawling fleet is small, the vessels are larger and more modern than those of other Eastern Mediterranean countries. The 25 vessels include steam trawlers (some of 50 to 60 tons, equipped with electrically refrigerated holds and echo sounders) and several new, imported diesel trawlers 20 meters long and with 150-horsepower engines. Trawling from the newer vessels is done at depths from 40 to 150 fathoms, but surface fish are sought when the deep-water catch is meager. Other up-to-date trawlers have been ordered, partly in Israel and partly from European yards.

Extended Range

In 1954-1955 the average annual haul per trawler was 70 tons, and the largest vessels brought in as much as 120 tons. This is higher than the catch of the average Mediterranean trawling fleet, owing to the larger vessels and new gear, which have extended the cruising range.

On the other hand, the use of modern equipment has raised deep-sea fishing costs to the point where the price of the domestic catch is no cheaper than the price of imports. Half of the total trawling catch is red mullet. The rest consists of ocean perch, snappers, hake, soles, groupers, and so on.

Purse Seining In Summer

Deep-sea trawling takes place the year round. There are, however, certain limiting factors. First, some of the richer, shallow grounds are close to foreign territorial waters. Second, storms and attendant bad weather cause loss of fishing time during the winter. Third, rich surface fishing waters attract a number of vessels away from trawling to purse seining during the summer.

Traditionally, the shallow grounds that extend up from the Nile Delta to the Gaza coastal strip have been the richest for trawling. Here the continental shelf extends well off-shore, while narrowing off Tel Aviv and Atlith. These waters receive nutritive salts from the silt brought down by the Nile and thus attract many fish.

Small red mullet constitutes the bulk of the catch, but the "locus" (Epinephelus, a grouper) is especially prized. This is a fairly big fish, 20 to 30 pounds in weight. Some of the larger Israeli trawlers, as well as smaller vessels, work these southern grounds during the summer, when the Nile flooding makes the waters most fertile.

Unloaded Off Tel Aviv

The larger trawlers stay at sea for as much as two weeks, fishing day and night, and keeping radio contact with a special radio station at Jaffa. The catch is unloaded at the open-roadstead harbor of Tel Aviv, to take advantage of the country's largest population concentration and consumer market.

Fishing close to Egyptian territorial waters has been hazardous because of friction over possible territorial water violations. Most vessels have moved out to deeper waters west of Haifa or off the Turkish coast. Indeed, the necessity of skirting the productive grounds off the Nile Delta and moving out to deeper, but safer, waters, has been an important stimulus to the rapid modernization of the trawling fleet. With Israel's victory in the Sinai Peninsula, Israeli fishermen may now feel more secure about fishing off the Gaza Strip, and more frequent fishing in these southern waters is anticipated.

New Turkish Fishing Area

In August of 1952, especially rich grounds were discovered off the Turkish coast near Iskenderon, 200 miles north of Haifa. Since then extensive fishing has been carried on there during the summer, despite the proximity to Turkish territorial waters. In December, 1955, and again in April, 1956, Israeli trawlers were seized several miles offshore by Turkish authorities for alleged violations of these waters.

Choosing between deeper, but less productive and less sheltered fishing areas in the central Levantine Basin and the richer, shallower grounds nearer to Turkey and Egypt presents a dilemma to Israeli fishermen. In ranging over increasing distances in the Eastern Mediterranean, the trawlermen cannot avoid competition and international friction.

In addition to the larger vessels, smaller smacks trawl to 100 fathoms and motor boats ply closer to the coast. These all rely on ice, not refrigeration. In the winter they are confined to surface fishing within shel-

tered Haifa Bay. In the summer they move off-shore, trawling for mullet in waters 20 to 30 fathoms deep. In contrast, some of the larger trawlers, which work in the open Mediterranean during the winter, turn to catching sardines with purse seines in the summer.

Surface and Coastal Fishing

Surface and coastal fishing accounted for 1050 tons in 1954-1955. Surface-water fishing is carried on from small, relatively modern boats; coastal fishing uses the more primitive line and net methods and is still conducted in part by Arabs.

Fishing in surface waters is a recent practice among Jewish fishermen in Israel. The upper-level waters, almost untapped until 1949-1950, yielded 241 tons of fish in that year and doubled their yields in the following seasons. Because of an unusual scarcity of sardines, the chief surface catch dropped in 1952-53. The sardine run is heaviest in the summer, as the fish come to the shallow waters to

HAIFA, CHIEF PORT OF ISRAEL, *is the center of the country's seagoing fishing fleet. Good shore facilities, deep and sheltered harbor and ease of access inland, give it advantages that neither Acre nor Jaffa can match. (Israel Office of Information)*

feed after spawning out at sea in May and June. The run is also heavy from October to December as they move out to sea.

Not Much Tuna

Employment of modern techniques has been spurred by Yugoslav and Italian instructors, who have taught Israelis the use of modern equipment and nets, powerful lights, and better vessels. Today most of Israel's 300 small boats and smacks (motor, oar and sail) and some trawlers (which shift to purse nets in making seasonal adjustments from the deeper to the upper waters) bring in a varied catch that includes sardines, mackerel, groupers and gray mullet. Tuna fishing has not been highly developed, and it may well be that the tuna runs of Portugal, Sicily and Tripolitania simply do not extend to the Eastern Mediterranean.

Various methods are employed in surface fishing, of which "light" or "lux" fishing ("lampara") is the most important. The boats work only on moonless nights. Small boats, searchers, carry a 4,000 to 6,000-volt lamp to attract the fish, and others bring in the catch with the nets. During the best seasons for "light" fishing (October through December and May through July), sheltered surface waters along Israel's coast are lit up in the evenings by dozens of lights.

"Light" Fishing Not New

Haifa Bay is the main center, because of its shallowness, absence of rocks and general concentration of fishing. Fishing with lights is, of course, not new; the Arabs used lamps to catch sardines in the summer. What is new is the equipment and techniques that Jewish fishermen are using. Nearly half of the surface catch comes from this type of fishing.

Purse-seine fishing from small boats accounts for the rest of the surface catch. A variety of nets are used; the most important is the "chinchola," which brings in about one-third of the surface fish, and which is also used by the small trawlers that turn to surface fishing at the peak sardine feeding periods. Purse seining from larger vessels holds the greatest opportunity for the expansion of pelagic fishing, because of the greater ranges that can be covered.

Convertible Boats

A Turkish-type net, "reshet hakitor," cast from small rowboats, is also used in surface fishing. At the end of the season these boats are converted to wintertime coastal fishing and are used for angling in the rivers and along the beaches. Thus there is flexibility of equipment and men not only among the larger boats, which shift from trawling to surface fishing, but also among the small boats, which change from surface to coastal waters.

Coastal fishing, once entirely in Arab hands and rather primitive, is carried on with both shore nets and long lines. Jewish fishermen began coastal fishing in 1949. With Arabs, they work in teams, either part or full time. The advantage of working in teams lies in the greater ease of shifting to surface fishing during the sardine runs. The teams that have managed to achieve this flexibility and to improve their methods of coastal fishing have succeeded.

Of methods of coastal fishing, long-lining is the most important, catching the "locus" as it comes inshore to spawn, and the "farin," a flat, white fish. Long-lining takes about 45 per cent of the coastal catch. "Jarif" fishing, or beach seining, brings in about 25 per cent, and the "kirguira" (a Turkish net launched from rowboats) and individual cast netting account for the rest.

Long-Distance Banks Fishing

In 1951 and 1952 efforts were made to establish an Israel-based banks fishing industry. The trawlers fished first off the Icelandic banks and the coast of northern Norway, then moved to the Canary Islands. The total catch for 1950-1951 was 1,551 tons. Since the Israeli have not developed a taste for salted fish, the catch was frozen in the vessels' refrigerators and taken to Israel.

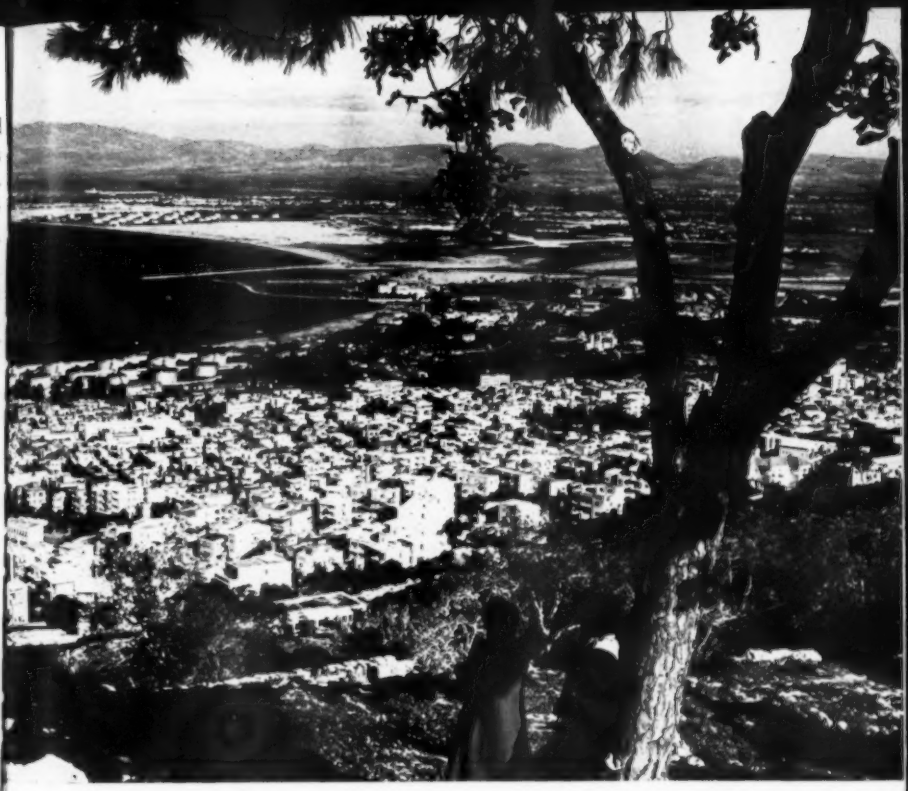
Operations ceased, owing to difficulties with equipment and management, after a catch of only 333 tons in 1951-1952. Since then Israel's long-distance banks fishing industry has remained at a stand-still, though authorities are vitally concerned with its re-establishment. Preparations are being made by Nakhshon, Ltd., the country's largest fishing company, to enter this field.

The problems are manifold. The grounds of the Dogger Bank and the Grand Banks are too far away to be fished profitably. The nearest important fishing grounds are along the African west coast (Canary Islands and south to Dakar), where cod and flatfish are plentiful. However, the distance from Haifa to West Africa and the Canaries is still considerable, and the warmth of the climate and waters requires the utmost efficiency in refrigeration. Fishing circles are now surveying the possibilities either of acquiring a factory ship to fillet the fish, manufacture oil from the livers, and make meal from the waste, or of acquiring several deep-freeze fish trawlers.

On a factory ship the catch would be completely utilized. But the problems of acquiring skilled personnel, especially for cutting and filleting, and of remaining at sea for half a year at a time, are formidable. There are also fuel costs and machinery maintenance. On the other hand, deep-freeze trawlers carry an unnecessary load of 50 per cent of the catch. The time to and from the grounds for a 550-ton ship is estimated at 20 to 22 days. With 14 days of fishing, eight journeys at most could be made in a year. Such a vessel, with a capacity of 250 tons of fish, could therefore bring in a maximum of 2,000 tons in a year, of which only 1,000 tons would be edible.

Advantages of Factory Ship

A recent proposal would combine elements of both types of ships in an experimental, medium-sized trawler, to be ordered from a German shipyard. This ship would have a deep-freezing plant (capacity, one ton of fish an hour), a refrigerated fishhold, and a small fish meal plant for the trash fish of the catch. The yield would be about 1,500 metric tons of fish annually, or about 750 tons of edible fish. Space for a small filleting plant would be provided. Thus the



THE HISTORIC PORT OF HAIFA, *as seen from Mt. Carmel. In late fall and late spring, on moonless nights, the bay looks like a bowl full of fireflies as fishermen in small boats use bright lights to attract fish into their nets. (Israel Office of Information)*.

vessel, though not planned as a factory ship, could be converted into one if circumstances should warrant it.

In general, it would probably be more feasible to plan for several large and medium-sized deep-freeze trawlers than for one large factory ship. But, as elsewhere, there is need for flexibility in allowing for an interchange of the various types of vessels and techniques. The time for re-entering the long-distance bank fishing industry is at hand, and fishing circles in Israel, though cautious, look forward to exploiting the banks.

Chief Fishing Ports

Haifa, chief port of Israel, is the center of the country's seagoing fishing fleet. The deep, sheltered waters, excellent shore facilities, and ease of access inland, southeastward through the Valley of Jezreel and southward along the coast, give Haifa advantages that neither Acre nor Jaffa can match. These advantages are as eagerly sought by fishing vessels as by cargo and passenger ships.

Jaffa and Tel Aviv, closer to the population center of Israel, might be

deemed more logical bases for salt-water fishing. The shallowness of their open roadsteads building up main fishing bases and they are lighter ports only.

However, the concentration of the trawlers in Haifa port contributes to shipping congestion. There is no room for additional fishing vessels within the port. Furthermore, the expansion of general cargo facilities is blocked by the space taken up by the fishing dock. Plans have therefore been drawn up to divide the fishing fleet and move it to other main stations, one at a special wharf to be built on the Kishon Ship Canal, just southeast of the port, and the second at Caesaria harbor, south of Haifa port.

Some New Facilities

The Kishon Ship Canal is an inland port, an auxiliary to Haifa. The lower course of the Kishon River has been straightened and dredged. A few wharves and warehouses were completed in 1955 and were used in the export of part of the citrus crop. The fishing base will entail the extension of the canal eastward, just above the warehouse area, and the building of a special wharf. The wharf will be 180 meters long, more than adequate for Israel's entire fishing fleet.

Work is also progressing on a fishing wharf and breakwater at Caesaria. When this fishing harbor is completed, it will provide a draft of five meters and will be able to handle from 10 to 20 trawlers. A refrigerated storehouse is to be built adjoining the wharf. A fishing port here offers certain marketing advantages. Caesaria is closer to Tel Aviv—an hour's ride by truck—than Haifa is, and is directly off the coastal highway. However, harbor facilities are far more important than market advantages when the distances are so short.

Several small coves along the coast shelter fishing bases. Sdot Yam, a collective settlement just south of Caesaria, has one trawler and is acquiring two more. This settlement can concentrate on agriculture in the off-fishing season.

North of Kfar Vitkin is the small fishing village of Michmoreth. The harbor, well protected by a small breakwater, has been dredged to a depth of three meters, and a small dock has been built. This is the site of the government's fishing school, and three trawlers are located there. Gesher Haziv, a collective farm village north of Acre, has one boat and may have potentiality as a small fishing center, depending upon the energy of the settlers.

Eilat and the Gulf of Aqaba

During the time of the Palestine mandate, a few hundred tons of fish were caught each year by Arabs in the warm, greenish-blue waters of the Gulf of Aqaba, a northwestern arm of the Red Sea. These waters, well stocked with tropical fish, corals and sponges, have scarcely been tapped for commercial fishing. Surface-water temperatures that are high in summer but low in winter contain large amounts of nitrates and phosphates. Strong currents and upwellings of subsurface waters, combine to give variety and a fair degree of abundance to marine life, especially in the

shallow, off-shore waters. On the other hand, most of the Gulf's waters are deep and highly saline—definite handicaps to large-scale fishing developments.

Until Israel's victory over Egypt in the Sinai campaign, the latter's blockade of the Straits of Tiran prevented the development of an Israeli trawling industry in the Gulf of Aqaba and the Red Sea. The recent opening of the Gulf of Aqaba has geopolitical impact, for it gives Israel access to the Indian Ocean and an overland route that is an alternative to the Suez Canal. General economic activities at the port of Eilat are moving forward at a feverish pace. The town's population has more than doubled; off-shore tanker unloading facilities and oil storage tanks have been built; an eight-inch pipeline has been completed from Eilat to Beersheba to transport Persian Gulf crude oil; and port facilities capable of handling nearly 100,000 tons of general cargo are under construction.

All of these activities will spur the development of Israel's Aqaba fisheries. To date, most of the fishing has been of the coastal and surface variety, with nets cast from either the shore or rowboats (although an occasional foreign trawler has unloaded at Eilat). What was not consumed locally was shipped by air to Tel Aviv. Future plans call for trawling activities in the Gulf of Aqaba, and possibly the Red Sea, increased coastal and surface fishing and the development of winter sport fishing on the Eilat shores.

There are three obstacles to the development of deep-sea trawling at Eilat: poor land transportation, hazards in using Red Sea fishing grounds, and lack of a large local market. Present connections between Eilat and Israel's main population centers are by road (eight hours of unpaved road to Beersheba, and thence by modern highway to Tel Aviv—a total distance of 290 kilometers), or by air. Neither route is feasible for the economical transport of fish. What is needed is a paved highway and a rail line — for these are basic to the economic development of the Negeb and Eilat. Construction of the highway is now underway and plans for the railroad are being formulated.

Future Prospects

Israel's fishing industry has been viewed against the background of population requirements. Per capita consumption of 28 pounds of fish annually is moderately high. It cannot, of course, compare with Norwegian or Japanese consumption (about 65 pounds per person), but it is close to the United Kingdom's (33 pounds) and Portugal's (28 pounds) and outstrips that of Greece (17 pounds).

Simply to hold consumption at the current level, in the face of an increasing population, will sorely try both foreign-exchange resources and the domestic fishing industry. It is estimated that Israel's population will reach two million by the end of 1958. If fish consumption is to remain at the present level, the country will then need 25,000 tons of fish.

The present trade imbalance makes it vital to prevent fish imports from rising still further. The burden on the

ALTHOUGH THE TRAWLING FLEET OF ISRAEL *is small, the vessels are larger and more modern than those of other Eastern Mediterranean countries. Trawling is carried on in the surface and intermediate water layers at distances of 4 to 20 miles offshore. (Israel Office of Information)*

domestic fishing industry will therefore become increasingly heavy. The best possibilities for rapid expansion lie in ocean-banks fishing and deep-sea trawling, both of which require high capital expenditures. The purchase of additional boats and equipment from German shipyards under the Israel-German reparations agreement is to be expected. But larger vessels, complex equipment and highly skilled labor are not necessarily the only answers.

Manpower Flexibility

Flexibility in the use of vessels and equipment is especially important, as we have seen. Manpower must also be flexible. There are today 1,200 Jewish fishermen. Israel can draw upon a manpower reserve from two sources: the agricultural collective or cooperative villages along the coast, and the Arab population. It may be feasible to encourage villages near Haifa or Caesaria to own trawlers that can be based at the fishing wharves, and to take advantage of the fact that during times of poor fishing the part-time fishermen can be profitably occupied at farm tasks. Perhaps regional groups of villages could be encouraged to form pools, of both labor and boats, for use in the fishing industry.

The Arab population might be drawn upon more profitably. Today 300 Arabs earn their living from the sea. Most of them work in small companies owned by Arabs, and a substantial percentage of their earnings goes to the owner. Efforts are being made by the Israeli Department of Fisheries to get these men to form cooperatives and work for themselves.

Perhaps greater efforts should also be made to stimulate individual Arabs to ply their old trade without waiting for the new boats and equipment necessary to modernize the industry. Various government incentives may attract more Arabs, even with their outdated fishing methods, back to the sea. Their methods may be primitive, but their ability to catch fish makes their efforts as economical as those of the smaller companies, with their higher-cost modern fishing. Arab coastal fishermen would certainly be an asset to the development of the fisheries at Eilat.

Marine Science Needed

Certainly all possible avenues for increasing fish yields should be followed in the attempt to reduce Israel's dependence on imports. The outlook is one of expansion, although the relative poverty of fish in the Mediterranean makes the task challenging, and the continuation of some imports unavoidable. Marine science, economics and marketing, working hand in hand, may here, as in many other parts of the world, make the future easier for the people of Israel.

Coral Reef Battleground

By FREDERICK BROWAND

MUCH ROMANTIC FICTION has centered around the coral islands of tropical seas. But truth is even more fascinating than fiction and the very existence of coral reefs poses an interesting series of problems to the scientist. To the geologist they are important in forming land where no land previously existed. They protect shorelines by providing barriers against the angry seas. To the navigator they are often a death trap. To the biologist they are sustainers of life, a precise chemical and biological balance of the sea and a source of food to many peoples of the tropics. But, where do they come from and how do they grow?

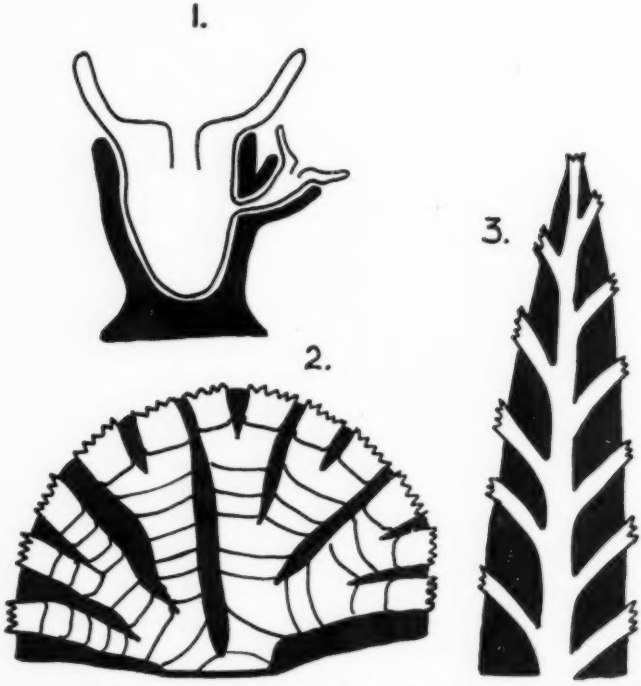
Darwin and The Coral Seas

Much of the scientific studies of reefs, by Darwin and his successors, has been carried out in the Indian and Pacific Oceans where true barrier reefs and atolls flourish, but strange to say, important work leading to an understanding of them has also come from Florida, which is sufficiently north of the equator to be just outside of the latitudes of the coral reef zone, which extend around the world in a belt roughly 1400 miles north and south of the equator. Nevertheless, although in some ways not typical, the Florida reefs have the same points of interest as coral reefs throughout the world and they are unique in being accessible to many hundreds of thousands of visitors who would otherwise never see these rocky growths. Some of the most important contributions to the unravelling of the coral reef mystery were made by the late Dr. Mayer, then Director of the Carnegie Laboratory on the island of Dry Tortugas, miles off Key West, beyond the tip of Florida, and by his colleagues, including Dr. Vaughan.

Ship Wreckers and a Challenge

Coral reefs have played an important part in man's development of South Florida. Key West originated as a "wrecking center," salvaging cargoes of ships that frequently crashed on the then unmarked reef. Today the reef shelters one of the finest game fishing grounds in the country, attracting many people. Its mere existence invites enquiry. The study of coral reefs today gives us an invaluable insight into geological developments of millions of years ago. Many of the coral reef's riddles cannot be fully solved but some insight may be gained from the facts and conditions present today.

ECAUSE MANY SMALL FISH *seek sanctuy within the sheltering arms of coral rmations, the inquisitive biologist ust approach closely to observe them. neath heavy elkhorn coral wave the nt-like fronds of soft coral, or gormians. (Ed Fisher)*

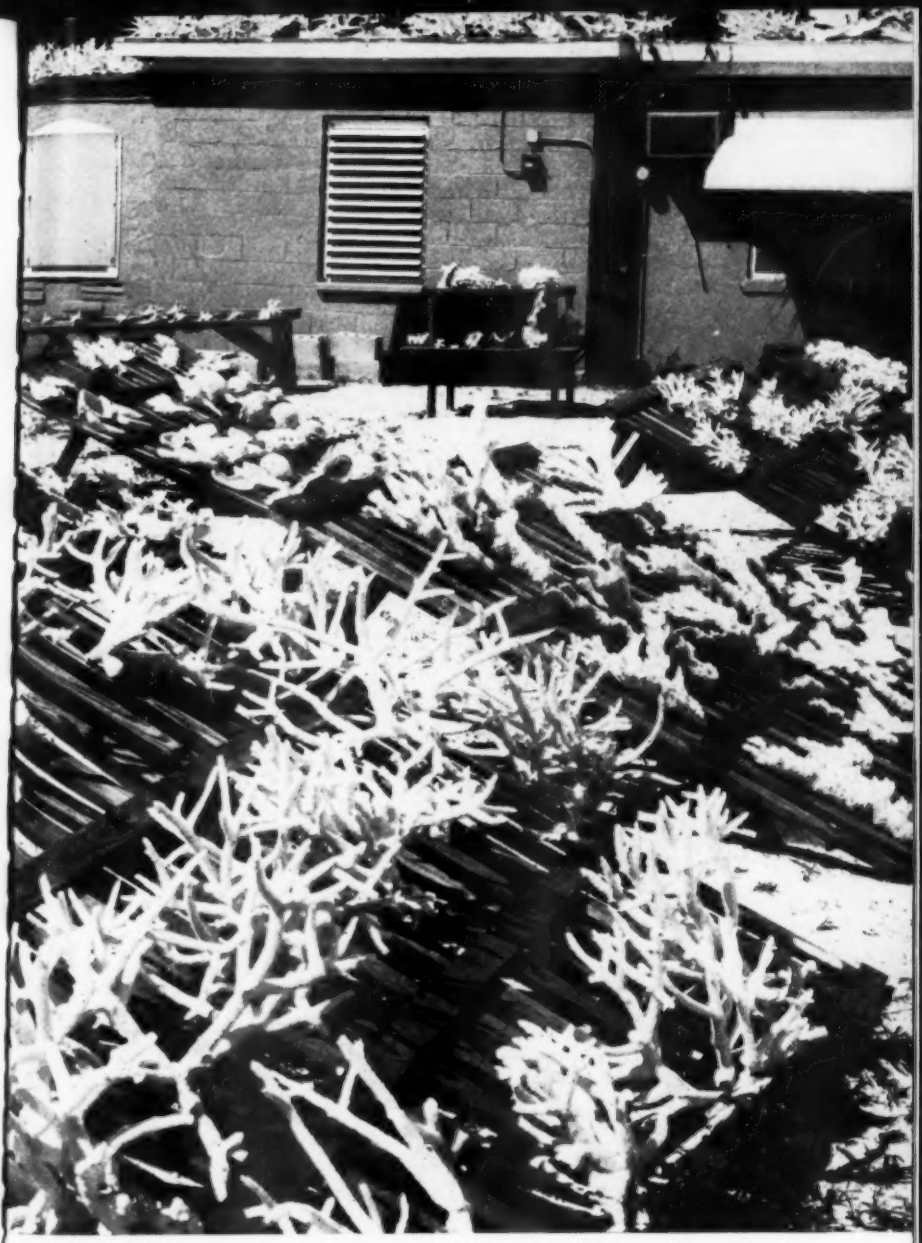


LENGTHWISE SECTIONS OF CORALS *illustrating modes of branching and colony formation. Greatly simplified. 1, lateral budding of a single polyp. 2, formation of a massive colony by growth and branching of the polyps, showing transverse partitions laid down as growth of the polyp progresses. 3, growth in which the original polyp continues to remain at the tip, forming branching colonies. Dark portion represents stony skeleton.*

We need not agree with authorities, for they also can only surmise. Herein lies a chance for the individual to use his powers of reasoning and his facilities for observation to best advantage and so reach a conclusion which is his alone. We may, then, think of coral reefs as a challenge.

No Coral Insects

At first glance it is hard to believe that corals are animals rather than plants. They grow sturdily attached to the bottom and have no apparent motion until one looks closely at the brightly colored tentacles and observes that they move about under their own power. But they are not "coral insects" as the books of our childhood had it. They are related to jelly fishes, hydras, and sea anemones. Each coral individual or polyp is a small tubular body with an opening at one end, its mouth. This is surrounded by tentacles. Its other end, the foot, is attached to some object. The lower surface of the coral



TREASURE FROM THE REEFS. *Corals of many varieties, but chiefly staghorn and elkhorn, on bleaching racks behind a souvenir shop in the Florida keys. Because certain fishes feed and live among living corals, marine scientists warn that continued heavy gathering of coral for sale may eventually deplete some of the best angling waters. (E. John Long)*

secretes a skeleton called corallum, which is composed mostly of carbonate of lime.

Not all corals are able to build reefs. Those that can have one thing in common. A form of algae or microscopic plant called *Zooxanthellae* lives inside the coral body. The algae receive food and carbon dioxide from their host, the coral, and the host, in turn, receives oxygen from the algae.

A Beautiful Beast

They are very hardy carnivores. Difficult as it is to imagine such small, beautifully colored, and delicate creatures as carnivorous, they are ruthlessly efficient, being equipped with numerous specialized food-getting mechanisms. The outer surface of the animal tissue throws out lasso-like stinging cells called nematocysts. It also secretes mucus, in which particles may become imbedded. Small hair-like projections called cilia move the mucus toward or away from the mouth as the occasion demands. The tentacles, whose primary job is to provide a showy attraction, are also active in capturing food.

Plantlike Buds

The main staples of diet, toward which all this activity is directed, are the small planktonic animals which are carried about by the wind, tides, and currents. Corals feed only at night and have a very powerful digestive system. As a result, the food is usually digested before daylight.

They reproduce sexually in animal fashion, but also in the asexual manner of plants. Small larvae called planulae develop from the fertilized eggs. They are cylindrical or pear-shaped and about one millimeter in length. After swimming in the sea for a few days to a few weeks, they attach themselves to some object.

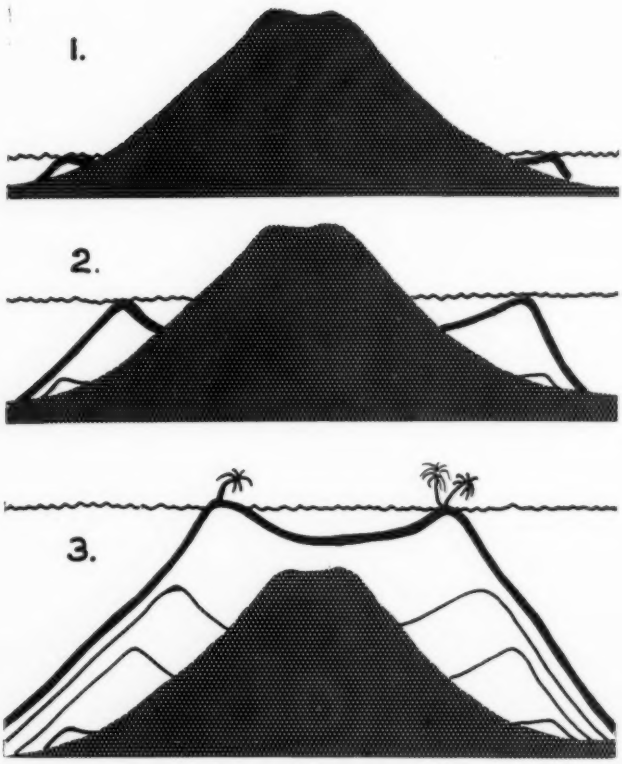
Colony-forming corals also multiply in plant fashion by budding or fission. A bud appears on the surface and shortly becomes a new polyp. In fission, a polyp divides equally or nearly equally to form another polyp which then divides. All polyps thus formed remain in contact with each other and through variations in the process, different types of colonies are evolved. Thick round masses form a class called Porites; similarly thick branches form Pocillopora; delicate shrub growth is labelled Acropora, and broad, leafy plates characterize the Montipora.

Reef Builders Need Food and Light

Marine biologists have discovered many things which influence the growth of reef-building corals. The massive ones are generally found in water less than one hundred feet deep, though some occur down to one hundred and fifty feet.

Corals found below this depth are not reef-builders. Two reasons have been found for this. Reef corals depend upon currents to supply them with food and, at greater depths, the weaker currents do not supply sufficient food for active growth. Also, the algae which live inside reef-build-

A SKINDIVER *toe-dances on the crest of big boulders of living coral, rising like a miniature hilltop from the rocky bottom. Coral heads such as these are constant menaces to deep draught ships. (Ed Fisher)*



SECTIONS ILLUSTRATING THE FORMATION OF BARRIER REEFS *and atolls according to Darwin's theory. 1, 2, 3 successive stages in the sinking of land beneath the water. 1, Fringing reef. 2, Barrier. 3, Atoll. Unshaded portion represents coral.*

ing corals, like other plants, are naturally very dependent upon light. The nearer the surface, the more light they absorb, and the greater the resulting growth.

True reef corals are usually found within a belt bounded by the tropics of Cancer and Capricorn, about 23½ degrees north and south of the equator. This is due to the fact that they cannot stand temperatures below 18 degrees Centigrade nor above 34.5 degrees Centigrade for any period of time. Temperatures most favorable to growth appear to be between 22 and 30 degrees Centigrade, typical of tropical seas.

Bury most corals in silt and they will die, but some have power to remove a remarkable amount of sediment. Corals of the outer reef are kept clean by the action of waves. Those living on inner flats require special adaptations. Some divide into upward pointing branches, leaving very little surface area to collect sedi-

ment. Others keep clean by the action of cilia.

Why Not Along Western Shores?

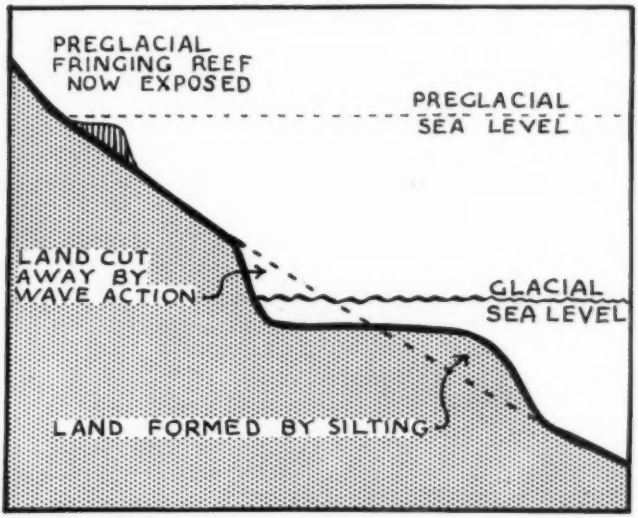
In order to grow, corals must have a suitable foundation. Almost any will do as long as it is firm. They cannot grow up from a muddy bottom. This condition, rather than suspended silt, may explain the absence of reefs from areas of great turbidity or muddy water.

True reef corals, even in the tropics, are not found universally, but only in certain well-defined areas. They are most abundant in the open tropical seas and on the eastern shores of continents. Why not along the western shores of continents? The oceanographer has an explanation. Since ocean currents are forced into a clockwise spiral movement by the earth's rotation and associated winds, warm water travels toward the poles along the eastern shores of continents. In return, cold currents run toward the equator along western shores, which are thus too cold for reef growth.

Four Types of Reefs

There is more than one kind of coral reef. Fringing reefs grow out directly from shore and are partly exposed at low tide. Barrier reefs are separated from shore by a lagoon.

TO THE NAVIGATOR, CORAL REEFS SPELL TROUBLE. *In July, 1957, the British cruise liner* Reina del Pacifico *ran hard aground on the coral heads off Bermuda. By removing cargo and enlisting the aid of tugs, the ship finally was refloated, fortunately with only minor damage. (Bernard Brown,* The Royal Gazette)



Section illustrating the formation of a platform by wave action in the marginal seas, during glaciation.

Atolls are oval-shaped reefs, enclosing lagoons. They occur miles from land and rise to the surface from ocean depths. A fourth type is sometimes overlooked, but it consists of coral pinnacles growing within the lagoons. The Florida reefs are somewhat intermediate between fringing and barrier reefs.

There are several well-defined areas to a reef. The reef flat is a stony expanse of dead coral behind the breakers, with a flat surface broken by shallow pools, irregular gullies, or potholes. The steep seaward slope of the reef is the place to observe reef growth in its most beautiful form. A ridge of coral-encrusting algae or Lithothamnion sometimes forms toward the outer edge, and is characterized by the fingered effect reaching out from the reef toward deeper water. The Lithothamnion ridge helps to break the force of the waves washing over the reef.

Pacific reefs grow more rapidly than do reefs in other localities. Actual measurements show a varied rate of growth, in the order of about 150 feet (in thickness) in from 1,800 to 7,500 years.

Cooperative Reef Builders

Corals are by no means the only stone builders present on a reef. The reef can be regarded as a group of animals, each contributing toward the whole mass. Certain types of marine algae also deposit limestone in their living tissue. The Lithothamnion has already been mentioned; another is the Halimeda. Both contribute limestone to the body of the reef and also act as cementing agents.

Other animals found on or near

the reef are sea anemones, barnacles, sea fans, sea whips, sea urchins, worms, shells, shrimp, spiny lobsters, crabs, sponges, and many types of tropical fishes. In this complex community some break down the rock, some build it up, but all contribute to reef formation.

The Mystery

Long a subject of heated argument, the manner of origin of barrier and atoll reefs is still shrouded in mystery. The problem is to explain how they began growth and upon what foundation they are erected. For reasons already stated, the foundation must be within 100 or 150 feet of the surface in order that the coral can live. Fringing reefs grow close to shore in shallow water. Their growth is upward and outward and so presents no problem to argue. Barrier reefs and atolls are an entirely different matter. Their foundations are below the depth at which corals can live and so their origin is open to question. Let us look at some of the more prominent explanations.

Darwin's Theory

The subsidence hypothesis, put forth by Charles Darwin, suggests the formation of barriers and atolls by a slow sinking of the land mass on which a fringing reef is growing. As the land subsides, the fringing reef keeps pace by upward growth, be-

IN THE FOREGROUND *runs the seaward edge of a living coral reef, traversed by narrow branching channels. Although clearly seen from the air, it is not visible from the sea until ships are almost directly over it. Obviously, a lighthouse is needed in such dangerous locations.*

comes separated from the sinking shore by a lagoon, and is thus transformed into a barrier reef. If the land mass is an island, further sinking will cause a wider and wider lagoon to form and finally, as the island sinks below the sea, the reef becomes an atoll. Debris washes over the leeward side of the reef, forming a roughly level lagoon floor.

The glacial control hypothesis was advanced by R. A. Daly. During the glacial age, when water was trapped in the polar ice caps, the resultant sea level lowering was accompanied by cooling seas in which corals were unable to grow. At the level of the lowered sea, the waves cut platforms into the land. Many islands were entirely flattened, while others merely had platforms cut into their sides. When the water warmed and the sea level rose, the corals grew upward and outward on these platforms. This theory has a logical explanation for a worldwide change in sea level.

Solution or Silt

Another theory requires that the coral grew up on immobile platforms, while the dead limestone in the center was dissolved to form the lagoon. On the other hand, Sir John Murray, of H. M. S. *Challenger* fame, believed that the platforms for the reefs were gradually built of silt, from deeper submarine ridges. More recently, Vaughan considered that reefs might be built on pre-existing platforms.

The Pros and Cons

Just what are the facts on which we may base a conclusion? First of all, evidence today points to the fact that there is a filling process taking place in the lagoons of most barriers and atolls. Therefore the solution theory must fall. There is some evidence for a pre-existing platform theory, but without sinking of the platform it is not possible to explain why the depth of most large lagoons is more than that at which corals can thrive. So, they could not have begun growth on such a platform.

There is much evidence of subsidence. In some cases arms of the sea extend into the land area and occupy the lower parts of valleys that must have been carried out by stream erosion well above sea level. These "drowned valleys" and the discovery below sea level of deposits of peat and the remains of land plants is good evidence of subsidence.

The question is, were the flats behind reefs formed by debris from the reef, as Darwin maintained, or were they present before the reef, as Vaughan and others maintained? If the flat is due to infilling, the reef would be situated on the outer edge. This is not the case in many instances.

Formation of Florida Reefs

Another test would be to see if the rock, upon which the lagoon is situated, had any kind of geological history before establishment of the reef. Sometimes this is the case. It is fairly well established that the Florida reefs

ITH NO AIR HOSE *to impede him, the derwater explorer now can safely aneuver over a variety of different pes of coral to obtain photographs of ef fishes in their native haunts. (Jerry reenberg)*

are growing on a platform consisting of a submerged ancient reef. The platform theory fails to account for the absence of corals during the formation of the platforms.

The theory is criticized also because Vaughan fails to explain the origin of the platforms. But does the fact that books lie on top of a desk require a knowledge of the process of manufacturing the desk? Davis has provided an answer though. He suggests that the death of corals, due to cold, would leave the land unprotected by reefs, during the glacial periods. Then the sea could cut into the land to form the platforms.

Objections to Glacial Control

There are too many objections to glacial-control for complete acceptance. First, many atolls are too large to have been formed by the flattening of islands by wave action and erosion. The central island would be rather large to be worn away. Wave erosion of volcanic islands is a slow process.

But, the low water level due to glaciation is an established fact. How can it best be included? How can we best indicate the formation of barriers and atolls? These questions cannot be answered with certainty. Davis, however, believes some combination of the subsidence and glacial-control theories is probably nearer the actual truth than any one taken separately. He applies glacial-control to the marginal zones of coral growth, furthest from the equator, where the presence of cliffs on islands shows the cutting action of the sea. In certain cases the antecedent-platform theory seems to present more convincing arguments. As a general rule, perhaps subsidence best explains conditions as they appear today. The mystery of the reefs is still a challenge.

For Further Reading:

Submarine Geology, by Dr. Francis P. Shepard. Harper & Brothers. New York. 1948.

Atlantic Reef Corals, by F. G. Walton Smith. University of Miami Press. Coral Gables, Fla. 1948.

25th Birthday at Solomons

CONGRATULATIONS are definitely in order for the Chesapeake Biological Laboratory, Solomons, Maryland, which this year celebrates twenty-five years of growth and progress since the dedication of the original laboratory building in 1932. A brochure has been compiled, presenting a brief history of the Laboratory. This booklet is adequately illustrated with photographs depicting important marine research in the area of the Patuxent River and the Chesapeake Bay.

Salmon Swim Record?

BECAUSE so little is known about the life of a salmon from the time it leaves fresh water rivers as a smolt and the period it reappears as an adult fish, considerable importance is being attached to the catching of a tagged British salmon off the coast of Greenland. According to an account in the English scientific journal *Nature*, this migrating salmon travelled 1,730 miles from northern Scotland, where it was tagged, Nov. 23, 1955, to waters south of Sukkertoppen, Greenland, where it was recaptured Oct. 15, 1956.

W. J. M. Menzies, of Aberdeen, and W. M. Shearer, of the Brown Trout Research Laboratory, Perthshire, who report the find, say it may give an important hint about the sea migrations and feeding grounds of salmon from Scottish rivers. There is also the prospect that this salmon established a long-distance record.

Fish Worse Than Snakes

ARE THERE ANY FISHES whose bite is as fatal to man as that of the rattlesnake? In the intertidal areas of the Indo-Pacific lurks the venomous stonefish (*Synanceja verrucosa* Bloch). Everywhere in the region it is dreaded by the natives for the potency of its pain-producing venom, a powerful neurotoxin. Although it does not always cause death, it is always extremely painful.

Copeia for August, 1957 describes two rapidly-fatal cases, one at Maké, Seychelles Islands, and the other at Pinda, Mozambique.

At Maké an Indian youth was walking among rocks near the shore of the bathing beach, Pont Larue. Suddenly he felt a sharp stab in the foot. He saw three punctures. Soon intense pain spread up his leg. Other bathers found a pirogue and took him to shore. By that time he had turned blue and was frothing at the mouth. Rushed to a hospital, he died on the way. The medical officer at the hospital found his body greatly cyanosed, and announced the cause of death as a cardiac or respiratory poison.

At Pinda two men, working along the margin of a reef in a canoe, went wading to spear fish. Soon one of them collapsed, then became delirious, but was able to stammer out that he had been stabbed in the foot by a "sherowa," as they call stonefish. Carried into the canoe, he became unconscious. Meanwhile the stonefish had been located, cut open, and its gall-bladder extracted — because natives believe the gall-bladder is an antidote to the poison. But the victim died an hour later. Doctors found the stab went along the bone, and the toxin may have been injected directly into the blood stream.

NEW FACTORY SHIPS, *where fish is processed aboard and then stored in deep freeze compartments aboard the vessel, is a notable step forward in fish saving. Here quick frozen fillets are being unloaded at Immingham Docks, near Hull, England. (Chr. Salvesen & Co.)*

Science of the Sea in Books

FISH SAVING — A HISTORY OF FISH PROCESSING FROM ANCIENT TO MODERN TIMES.

C. L. CUTTING. Philosophical Library. New York. 1956. $12.00.

The reputation which Dr. Cutting has built as one of the foremost scientists in the field of fish preservation will be enhanced as a result of this book. He will, in addition, gain a solid reputation as a historian. "Fish Saving" is a readable account of mankind's progress in developing methods of preventing the deterioration of seafoods, notoriously quick-spoiling commodities.

The book will be valuable to professional workers in fishery technology in providing background material of a very complete order. It should also find many interested lay readers, who will discover that fishing played a critical role in the foreign and domestic policies of many maritime countries. Fishing success, coupled with great skill in fish preservation, was a big factor in the economic and political health, for example, of the Dutch in the 17th century. Their huge fleet of "some 2000 sail" supplied an important part of the wealth of their homeland.

It is probably no coincidence that Dutch maritime supremacy began to decline about the same time that the quality of salt herring produced by their fishing fleets began to deteriorate. The discipline, organization and unity of purpose which were necessary to produce a uniformly high quality of preserved herring were the same attributes necessary to maintain national dominance.

The book is remarkable for completeness. This completeness is per-

haps even a defect. Detailed statistics of production and other minutiae at times interrupt the reader's interest in the narrative. Nonetheless, many readers totally uninterested in the genesis of fish salting or freezing will be entertained by accounts of the influence of fishing and fish trade on politics and national survival.

They will also be interested in such minor pieces of intelligence as the fact that Scottish folk of poor circumstances commonly eat salted cod, which they call " 'hairy Wullie', presumably from the rather fibrous appearance it has after desalting and boiling."

This book has a scholarly and scientific flavor. It has, perhaps, a little too much of the scientist's coolness and precision to be a widespread popular success, but many nonprofessional readers will nonetheless enjoy it. It is a welcome addition to oceanic literature, both as history and as fishery science.

—C. P. I.

ASPECTS OF DEEP SEA BIOLOGY.

N. B. MARSHALL. Philosophical Library. New York, 1954. $10.00. Hutchinson's Scientific and Technical Publications. London, 1954. £10.0.0.

Well illustrated in color and in black and white. Although essentially a review of a scientific subject, this handsome volume may also be commended to the intelligent nonscientific reader for its sustaining interest. It covers many aspects of life in the deep seas; especially with regard to the adaptation of deep-sea fishes and scattering layer organisms to the extreme conditions in which they live.

The first part of the book also gives a historical account of the development of this field of research, the methods used in investigation and the physical conditions met with in the dark waters of the deep.

Every marine biologist will want to have this book on his shelf. Many who do not have scientific training will find it well worth reading. Its able manner of presentation will open up for them an interesting new world.

LEAPER.

ROBERT M. MCCLUNG. William Morrow & Company. New York, 1957. $2.25.

Scientists are made, not born. Which means that the earlier a prospective scientist's interest and curiosity are aroused, the better. Not by the hopped-up, pseudo-science found in the paper-backs of the newstands, but by books like *Leaper,* which not only tell an exciting story, but do it with restraint and with some respect for technical accuracy.

Leaper is the saga of an Atlantic salmon, a much neglected fish, and the three hectic, thrill-packed years of his life. That it is written in simple, easy-flowing prose for younger readers, detracts nothing from its appeal and value to adults, who will recognize the parts played by fish ladders, anti-pollution devices, and other conservation measures.

Robert M. McClung has authored nine books on natural science for young readers. He holds an M. A. in zoology from Cornell, and was Curator of Mammals and Birds at the Bronx Zoo before he devoted all his time to writing. In addition to writing the text, Mr. McClung drew the numerous attractive sketches that point up the natural and man-made hazards of the salmon's adventurous life. E.J.L.

About the Authors

PAUL E. THOMPSON

One of the leading authorities in fishery research, Mr. Thompson has even taught such natural experts as Eskimos and Indians how to improve their fishing.

This unusual experience came during a four-year stretch in an Alaskan vocational school, where he conducted high school science and fishery courses.

Most of the rest of his professional career, nineteen years in all, has been spent with the U. S. Department of the Interior in fishery research and management. Mr. Thompson is a graduate of the University of Washington, with B.S. and M.S. degrees. He has served as assistant chief, Branch of Fishery Biology, Fish and Wildlife Service; has conducted field studies of oyster resources and shellfish culture in Puerto Rico and the Virgin Islands; and was the U. S. Observer, International Council for Exploration of the Sea, Copenhagen, Denmark, 1956.

At present Mr. Thompson is Acting Chief, Branch of Fishery Research, Bureau of Sport Fisheries and Wildlife, Washington, D. C.

FREDERICK K. BROWAND

To an avid spearfisherman like Mr. Browand, coral reefs were once only places which abounded in fish. But it was not long before he developed a desire to understand more about reef formations themselves.

For two years Mr. Browand was employed by the Geological Research Division of Shell Oil Company. During this period, he received much first hand information by exploring the fascinating reefs of the Bahamas, as well as those along the coast of Florida.

A native of Miami, Florida, Mr. Browand is now continuing his studies at the Massachusetts Institute of Technology.

ROBERT J. CONOVER

"I do some teaching, but most of my time is devoted to the study of the ecology of coastal salt ponds along the Rhode Island coast." Thus Dr. Conover summarizes his work for the Narragansett Marine Laboratory of the University of Rhode Island, on Narragansett Bay, where he has been assistant professor of marine biology since July, 1955. In this same year he received his Ph.D. from Yale University, after being graduated from Oberlin in 1950. In 1954-55 he was a Fulbright Scholar to England. Dr. Conover's chief scientific interests are distribution, physiology and production of zooplankton, phytoplankton-zooplankton relationships, and ecology and production of neritic waters.

SAUL B. COHEN

Dr. Cohen is currently on leave as Associate Professor of Geography, Boston University, to serve as Academic Consultant in Political Geography at the Naval War College, Newport, R. I. He is a recognized authority on the resources, history and political background of the significant Middle East area. His articles on the political geography of this and other regions have appeared in the Geographical Review, the Professional Geographer, The Military Review, etc. Dr. Cohen has another interest, marketing geography, and he serves as consultant to several firms in the field of location analysis. "Currently," he adds, "the delightful view that my office affords me of Narragansett Bay whets my interest in additional fishing industry studies."

Progress

IN THE SHORT PERIOD of its life, *Sea Frontiers* has now reached a circulation of 12,000, not all of whom are members. They are drawn from the United States, Canada, Central and South America, Great Britian, Australia, France, Germany, Italy, Denmark, Sweden and Norway, as well as a few from the Pacific Islands and the West Indies. Continued improvement will be possible with growth of active membership. It will be seen in better service, with more articles in the Bulletin of high interest and authenticity and, eventually, a monthly issue in full color.

Members are joined in these aims and they are urged to make progress possible by taking the small effort needed to enlist new members. To those who are not members, but whose interest and curiosity lie in the sea and the spirit of discovery, there is extended an invitation to participate by simply mailing a card. The ocean is our last frontier and its exploration still under way.

The editor will be glad to consider for publication articles and illustrations covering explorations, discoveries or advances in our knowledge of the marine sciences or describing the activities of oceanographic laboratories or expeditions in any part of the world.

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Qualifications for membership are an interest in the oceans and a desire to extend and develop scientific research and exploration into them. Support given to research through personal activities or donations is recognized by the Foundation through the following classes of membership. Members are those who make annual contributions of $5, Fellows $25 annually; Life Fellows are those who contribute $200 or more or who have otherwise helped to advance the purposes of the Foundation; Sponsors who contribute $1,000 or more; and Patrons who contribute $5,000 or more.

Four dollars of each annual donation is for subscription to *Sea Frontiers* for one year.

According to a ruling of the U.S. Treasury Department, donations made to the Foundation are deductible in computing taxable income as provided for by the 1954 code.

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439 Anastasia Avenue, Coral Gables 34, Florida

PRINTED BY PARKER, CORAL GABLES, FLORIDA, U.S.A.